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Exploring natural and induced drivers in the Magdalena River discharge impacting the Ciénaga Grande de Santa Marta coastal-lagoon ecosystem

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Magdalena's river basin represents a quarter of Colombia's surface, yet neighbouring ecosystems remain ignored while enduring unacceptable environmental conditions. At its outlet in the Caribbean Sea, several channels link it to Cienaga Grande de Santa Marta (CGSM), a deltaic coastal-lagoon ecosystem (4200 km^2) from which around 15 to 20 % are water bodies. According to several studies, Magdalena River's overflows represent its primary freshwater source. However, the recorded discharge has gradually reduced, though the basin's rainfall shows a rising tendency. Additional discharge measurements close to the outlet evidenced that it was even lesser than records upstream counterintuitively. Consequently, the energy gradient from the river to the sea through the ecosystem is reversing more frequently. That has resulted in a continuous salinisation process of the lagoons, diminishment of the mangrove forest and lagoons extension, fauna migration and low water quality. This research aims to elaborate on the Magdalena River's outlet discharges vulnerabilities in Colombia, thus providing better insight into impact-based decision-making.

Results suggest that the discharge regime responds to the El Niño Southern Oscillation (ENSO) phenomenon as it controls the country's dry/rain season. Further analysis indicates that a) low flows relate to El Niño periods and high flows to La Niña; b) the flow duration curve's slope is getting milder, meaning that high flows are decreasing whereas low flows are increasing; c) extreme discharges are getting smoother, and less disperse so that high and low flow peaks are within a smaller range; d) the dispersion diminishes radically during severe El Niño events, and e) although a priori the assumption is that the more severe El Niño events might bring lower discharge values, the minimum values recorded are more significant than in neutral ENSO conditions.

Moreover, extreme discharge values during ENSO events, despite their severity, tended to have a horizontal asymptote that suggests human-driven control upstream, especially during El Niño periods. The Magdalena basin holds Colombia's hydropower network representing more than 70% of its electricity supply distributed in 33 operating plants. On the one hand, it is clear that during El Niño, the plants guarantee a minimum discharge downstream, as it is when the National

Hydrometeorological Agency only considers drought protocols. However, during neutral ENSO conditions, the flows are not controlled and thus, impacts downstream arise. On the other hand, reservoirs have increased evaporation due to a large accumulated open water surface (611 km^2 in total). Results show that water loss represents 40% to 80% of the current average discharge at the outlet (7000 m^3/s), adding to the ecosystem depletion. The results urge decision-makers to reconsider the drought protocols applying an impact-based approach.