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Using remote sensing to monitor the influence of river discharge on watershed outlets and adjacent coral Reefs: Magdalena River and Rosario Islands, Colombia

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ABSTRACT

Worldwide, coral reef ecosystems are being increasingly threatened by sediments loads from river discharges, which in turn are influenced by changing rainfall patterns due to climate change and by growing human activity in their watersheds. In this case study, we explored the applicability of using remote sensing (RS) technology to estimate and monitor the relationship between water quality at the coral reefs around the Rosario Islands, in the Caribbean Sea, and the rainfall patterns in the Magdalena River watershed. From the Moderate Resolution Imaging Spectroradiometer (MODIS), this study used the water surface reflectance product (MOD09GQ) to estimate water surface reflectance as a proxy for sediment concentration and the land cover product (MCD12Q1 V51) to characterize land cover of the watershed. Rainfall was estimated by using the 3B43 V7 product from the Tropical Rainforest Measuring Mission (TRMM). For the first trimester of each year, we investigated the inter-annual temporal variation in water surface reflectance at the Rosario Islands and at the three main mouths of the Magdalena River watershed. No increasing or decreasing trends of water surface reflectance were detected for any of the sites for the study period 2001–2014 ($p > 0.05$) but significant correlations were detected among the trends of each site at the watershed mouths ($r = 0.57$–0.90, $p < 0.05$) and between them and the inter-annual variation in rainfall on the watershed ($r = 0.63$–0.67, $p < 0.05$). Those trimesters with above-normal water surface reflectance at the mouths and above-normal rainfall at the watershed coincided with La Niña conditions while the opposite was the case during El Niño conditions. Although, a preliminary analysis of inter-annual land cover trends found only cropland cover in the watershed to be significantly correlated with water surface reflectance at two of the watershed mouths ($r = 0.58$ and 0.63, $p < 0.05$), the validation analysis draw only a 40.7% of accuracy in this land cover classification. This requires further analysis to confirm the impact of the cropland on the water quality at the watershed outlets. Spatial analysis with MOD09GQ imagery detected the overpass of river plumes from Barbacoas Bay over the Rosario Islands waters.

1. Introduction

Water turbidity and associated light attenuation, resulting from excessive sediment deposition rates are factors widely known to limit coral reef development. The effects of terrigenous sediments have been suggested to be among the main factors leading to the deterioration of coral reefs in a 145 km^2 complex of coral continental shelf reef located around the Rosario Islands (Díaz et al., 2000; Cendales et al., 2002), in the southeastern Caribbean Sea offshore 30 km from Cartagena, Colombia (Figs. 1 and 2). Runoff and maximum water discharge have been identified as the main physical determinants of sediment yield from the Magdalena River near the

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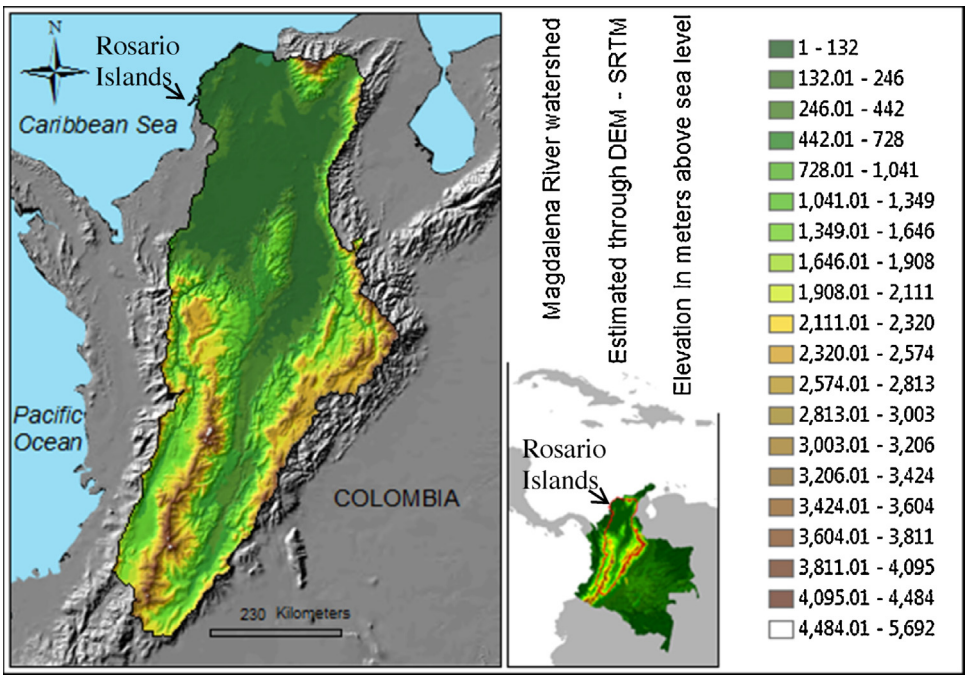

Fig. 1. Location of Rosario Islands at the outputs of the Magdalena River and location of the Magdalena River Basin in Colombia and South America.

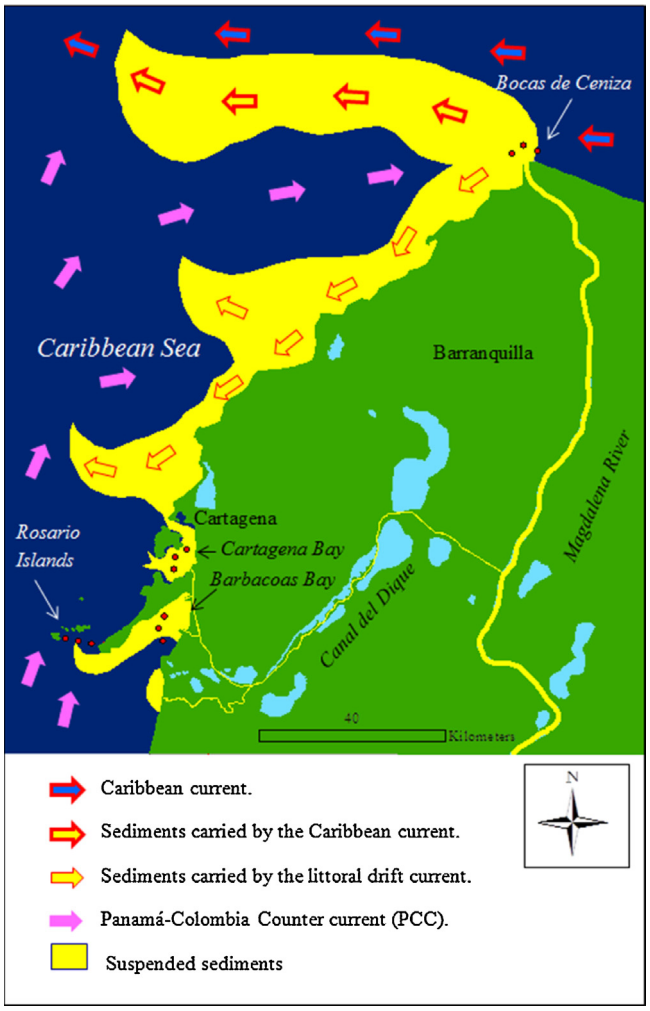

Fig. 2. Site locations and dispersion of the Magdalena River sediments in the Sea.

islands (Restrepo et al., 2006a). Regarding, cultural determinants, it has been proposed that continuous dredging and enlargement in a channel that divert waters from the Magdalena River along with the increasing human activities on the river watershed are among the main factors negatively affecting the coral reef of the Rosario Islands (Restrepo et al., 2006b; Mogollón-Vélez, 2013). It is clear that identifying the main stressors on the islands' corals is critical to effectively make corrections and plan ahead for proper sustainable management. Easily accessible cost efficient methods that facilitate long term ongoing analysis can be of high value. Such methods need to be proven for their sensitivity to identify potential spatial and temporal trends in the discharges and distribution of sediments likely to influence the coral reefs at the Rosario Islands. Knowledge of these trends will facilitate further studies to explore relationships with human activities in the watershed and mechanisms to correct or ameliorate negative effects.

A major difficulty to performing temporal trends investigations is the lack of historical *in situ* data as these are labor intensive, expensive and require investing long periods of time to accumulate enough data for analysis. Alternatively, remote sensing (RS) technology offers the advantage of archives for retrospective studies, with freely available data from places not monitored *in situ*, which could draw useful results in the short and long term. Surface reflectance MODIS (Moderate Resolution Imaging Spectroradiometer) 250 m product at 620–670 nm has been well established to estimate suspended sediments and turbidity in estuarine waters (Hu et al., 2004; Chen et al., 2007; Rodríguez-Guzmán and Gilbes-Santaella, 2009; Petus et al., 2010; Moreno Madriñan et al., 2010; Doxaran et al., 2009; Miller et al., 2011). The red section of the electromagnetic spectrum is commonly used in coastal waters to estimate sediments/turbidity because most of the reflectance spectra at this wavelength are dominated by suspended sediments rather than by pure water or other water constituents like phytoplankton and Colored Dissolved Organic Carbon (CDOM) (Mobley, 1994). We are unaware of any data on turbidity or total suspended matter concentration in our study sites for the time period of analysis. Given the scarcity of historical *in situ* data for the selected sites, this study was an effort to assess whether satellite data alone