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Feedbacks between Vegetation Cover, Hydrodynamics, and Sediment Transport in Tidally Dominated Tropical Deltas: a Remote Sensing Approach

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LONG-TERM GOALS

- To determine the feedbacks between mangrove vegetation and tidal hydrodynamics in tropical deltas with remote sensing data

OBJECTIVES

- To develop an algorithm for the extraction of deltaic morphology and topography from Landsat data.
- To quantify the effect of the vegetation canopy on the development of mouth bar deposits in a tropical delta
- To integrate the feedbacks between morphodynamics and vegetation with the results of the Dynamics of Tropical Deltas DRI

APPROACH

We propose to analyze a fringe mangrove forest in the Mekong delta, Vietnam through Landsat images spanning from 1982 to 2013 (Figure 1). The goal is to determine what information (topography, vegetation density, and hydrodynamics) can be extracted from the temporal series of remote sensing images. To this end we will combine in an integrated framework high resolution elevation data, measurements of flow velocity, waves, and sediment concentration collected in the field to remote sensing images. A high resolution numerical model will complement and expand the collected field data across the entire fringe forest thus allowing a direct comparison with the satellite images.

The integrated remote sensing-geomorphological framework developed herein will enable the Navy to collect important information in denied areas directly from satellite images.

As a proof of concept, we will apply the newly developed model to the temporal series of Landsat images in the Mekong delta, unraveling the complex feedbacks between river flow, changes in elevation and mangrove canopy in a fast prograding system.

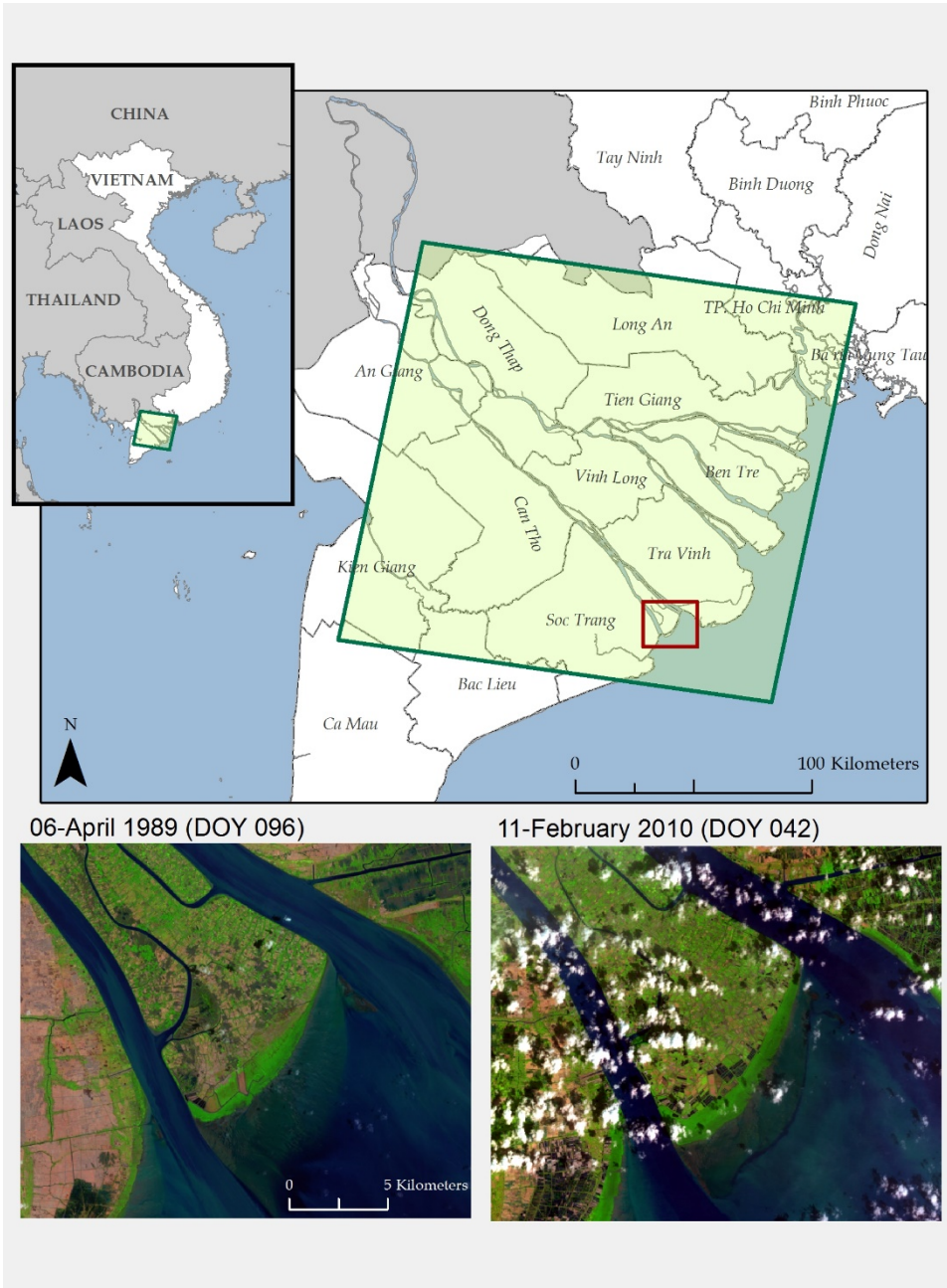

Figure 1. a) Mekong river delta, Vietnam. b) Landsat 5 ETM image from Apr. 6 1989 c) from Feb. 11 2010.

WORK COMPLETED

We analyzed decadal-scale changes of vegetation cover in a part of the Soc Trang coast. 158 Landsat satellite images, and one SRTM digital elevation scene, downloaded from UGSG Earth Explorer,

provided information about recent mangroves dynamics (Figure 2). Although Landsat 4, 5 and 7 have a 16-day revisit cycle, only 158 images of our area (path 125, row 53) have less than 80% cloud cover. The center of the scene is located at 10° 7' N and 105° 59' E. For all the images the acquisition time ranges between 2:20 and 3:15 PM. The images do not cover uniformly the study period: images are not available from April 1989 to August 1994 and from March 1997 to August 1999.

Due to the high cloud coverage during rainy seasons, most of the clear images are available from October/November to April. The dataset includes 100 images taken during the dry season, from November to April, while 58 are taken during the rainy season. Landsat images were processed to account for the presence of clouds.

We generated a numerical NDVI matrix overlaying tiff images. To study variations in NDVI indexes in time and space we chose 3 transects perpendicular to the vegetated boundary and a set of equidistant pixels on them.

The three transects were chosen based on vegetation dynamics at that location and number of available observations per pixel. 5 equidistant points spaced approximately 350m were chosen for transects 1 and 2, and only 3 points spaced 410m for the shorter transect 3.

In order to analyze the trend of the index along each transect, a subset of 6 images were chosen following these criteria: clearness of the image (absence of clouds and stripes); temporal equidistance of image acquisition; same month of acquisition. As a result, the six chosen images were acquired in March and April, at the end of dry season, 5-6 years apart.

Tides, periodically inundating mangroves, might influence the soil brightness and related indexes. To account for soil inundation, we used water level data from the Dinh An monitoring station n.985401 (data provided by The Mekong River Commission MRC).

Water level data from June 25th 2009 to November 26th 2012 are available, with 23 satellite images covering the same period.

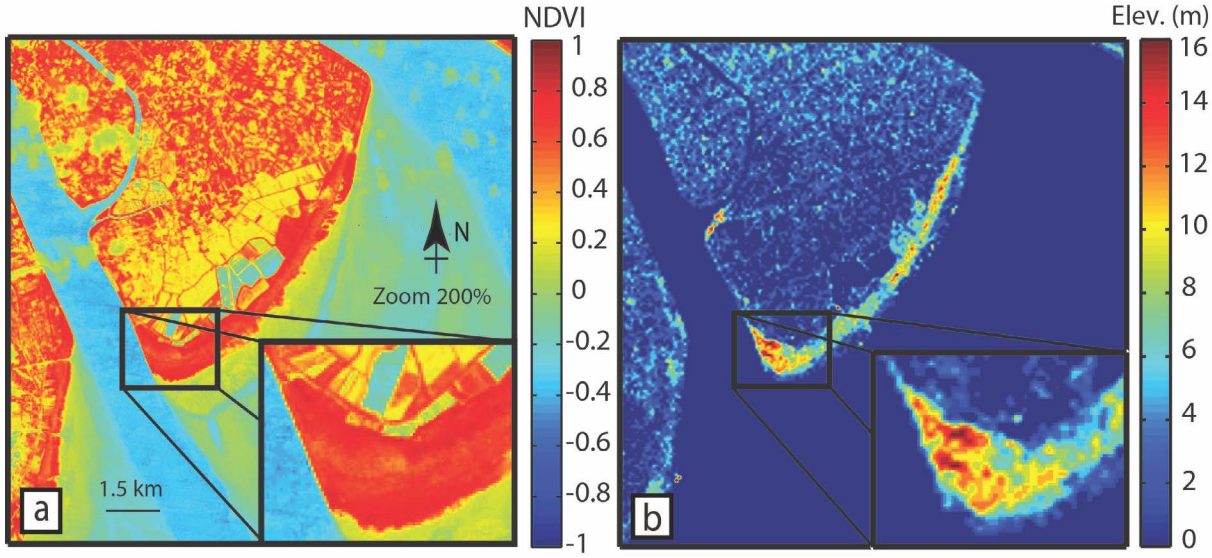

Figure 2. a) NDVI map (Landsat 5 Mar 3 2000) shows a lower value in the central part of the fringe. b) Digital elevation model derived by Shuttle Radar Topography Mission SRTM3N09E106V1 (Feb 11th 2000) displays high vegetation canopy in the central part of the fringe.

RESULTS

Seasonality plays a key role on vegetation brightness, maximizing vegetation index values at the end of the monsoon period. Tidal oscillations do not affect NDVI values in the mangrove forest.

Our results show that an increase in NDVI in the fringe is proceeded by fast mangrove expansion in the lateral part of the fringe near the river mouths. Because most sediment is discharged by the river mouths, the nearby mangrove fringe is homogeneous and presents a smooth, linear boundary with the ocean. On the contrary, the central part of the fringe, presenting a slower expansion, is characterized by a jagged boundary probably due to the erosive activity of waves. We also studied the relation between NDVI and the geometry of the fringe boundary using a linear correlation coefficient. A high coefficient indicates that the fringe boundary is smooth and linear. Moreover, we have computed a mangrove colonization rate from aerial photographs.

Two different vegetation behaviors emerge: (i) close to the river mouth the fringe contour is linear and the canopy expands uniformly on the tidal flats at high rate of colonization. This homogenous fringe border displays high NDVI values; (ii) in the central part of the fringe, the canopy progrades by vegetated patches showing low vegetation index values. The mangroves expansion rate is low compared to transect T1 and oscillates during the 2 decades of landssat data.

From a geomorphological point of view our studies show an important role of mangroves that can drive the resiliency of the system. High values of NDVI at the interface vegetation-water indicate a faster growth of the vegetated area in the previous years with an increased stability of the front canopy in the area close to the river mouth.

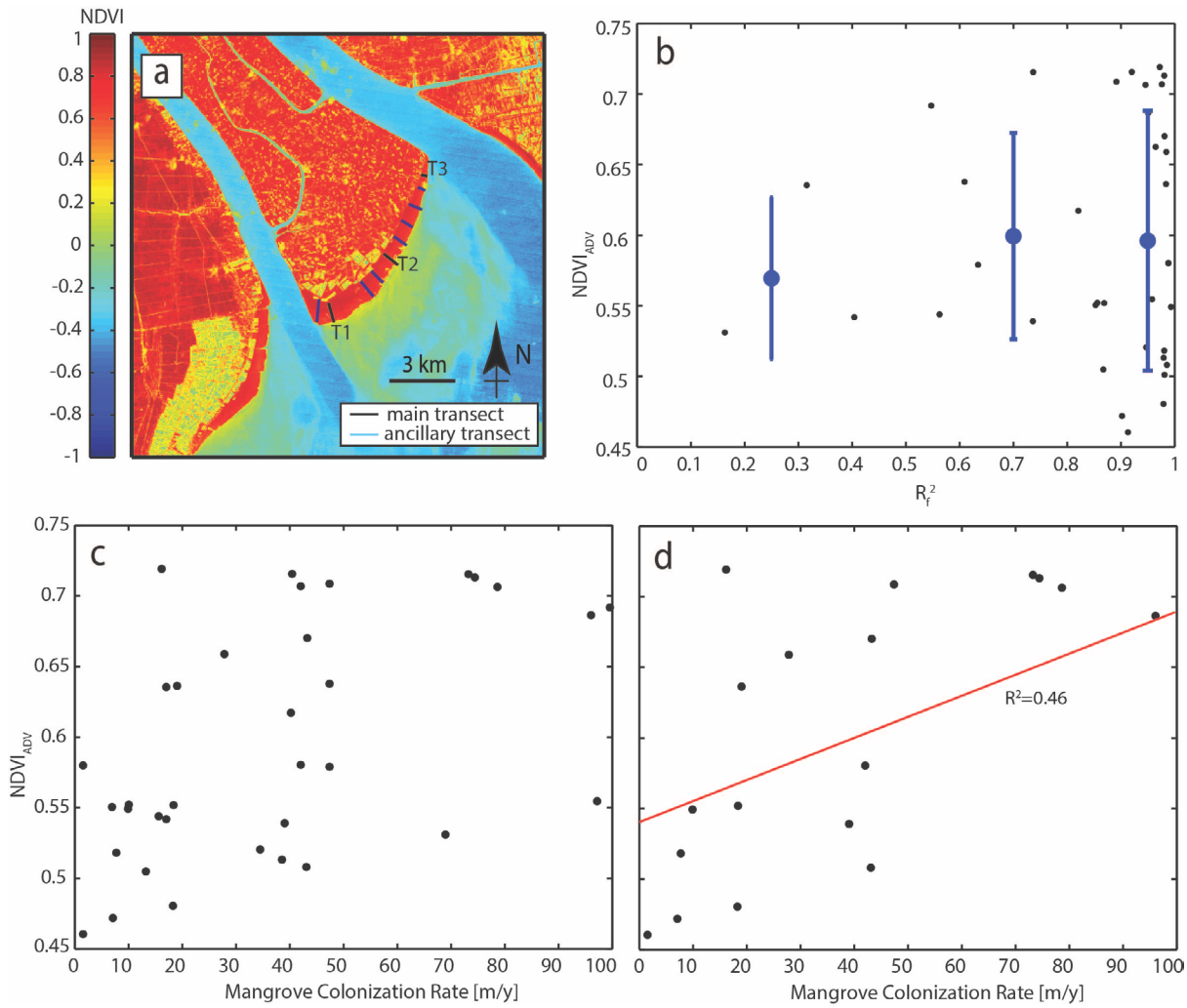

Figure 3. a) Position on nine transects on the mangroves fringe. b) Relationship between averaged NDVI and linearity of the fringe boundary R_f^2. c) Relationship between averaged NDVI and mangrove colonization rate for all the 9 transects. d) Relationship between averaged NDVI and mangrove colonization rate for fringe boundaries with high linearity (R_f^2>0.5). In this case the MCR is correlated to the average NDVI (R^2=0.36, p<0.05)

IMPACT/APPLICATIONS

The integrated remote sensing-geomorphological framework developed herein will enable the Navy to collect important information in dense mangrove canopies directly from satellite images

RELATED PROJECTS

This project is part of ONR-DRI Dynamics of Tropical Deltas

HONORS/AWARDS/PRIZES

Augusto Ghetti Prize for scientific studies on the Venice Lagoon, Italy. Venetian Academy of Arts and Sciences 2014