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.

![Study area in the Mekong river delta, Vietnam (a, d) Landsat 5 ETM image of February 11, 2010. The two aerial photographs b) and c) represent the study site with transects location (courtesy of Google Earth, Image 2006 GeoEye).](image)

**WORK COMPLETED**

Sediment samples for grain size and density analyses were collected along four transects in the fringe forest of Cu Lao Dung Island during low tide (Figure 1). Transects T1 and T2 are perpendicular to the shoreline while F1 and F2 run along the forest/water boundary (Figure 1). The data were collected every 30 m in order to match the Landsat resolution. The entire survey was carried out in fifteen days between September and October 2014 (from 10 Sep 2014 to 5 Oct 2014).

To determine forest characteristics, we also collected vegetation data along the four mangrove transects. We used the variable circular plot method (Groosenbaugh, 1952; Dilworth & Bell, 1975) to survey tree density. This technique allows efficient sampling of large trees that commonly have lower spatial density than small trees. In variable plot sampling, plot size is a function of trees diameter, and trees are accounted or not depending on whether their diameter at breast height (DBH) is large enough to subtend a fixed critical angle observable using an angle gauge from the plot center. Using a Basal Area Factor of 10, we tallied a total of 242 trees, an average of 8 trees per plot. Figure 3 shows a sketch of the natural vegetation variability found within the mangrove forest.
We further divided the sampled trees in 3 size categories (large, medium and small) and counted how many trees fell in each category within a radius of 10 m from the transect points. At each location we measured height and DBH of one tree representative of each category. A full survey of all trees in the plot was made impossible by the presence of very aggressive wasps that nested in large numbers on the Sonneratia trees.

Figure 2. Vegetation sequence along a) transect T1 and b) transect T2. Vertical dotted lines denote a forest or geological feature detected from remote sensing and field data. Different vegetation species identified on site are reported in the upper left corner of a). Trees dimensions are scaled following the dimensions measured in the field. Photographs show vegetation distribution in different zones of transect.
Figure 3. Relationships between the different variables measured along transects T1, T2 and along the fringe boundary F1, F2. a) BAF as a function of number of trees. Relationship between sediment density and percentage of b) organic matter and c) sand present in the sediment samples. d) Percentage of sand as a function of fraction of organic material. NDVI as a function of e) Basal Area Factor, f) number of trees, g) percentage of organic matter and h) percentage of sand in sediment samples indicated in Figure 2. Only NDVI data collected along T1 and T2 were used. i) Light Sensor (LS) as a function of BAF and j) number of trees.
Pendant data loggers HOBO were installed on 7 *Sonneratia* trees, 5 along transects T1 and 2 over T2, to measure light intensity at the same height of 1.8 m and same East orientation. The HOBO sensors measured the solar light that can penetrate the forest canopy. Given the unique spectral sensitivity of the instrument, the light sensor is most useful for determining relative changes in light intensity, rather than absolute values of intensity.

Geographical location was acquired with a handheld GPS (Global Positioning System). To establish relationships between the vegetation variables (BAF and number of trees), the NDVI index, and sediment characteristics we use linear regressions utilizing the available samples in the *Sonneratia* zone only.

**RESULTS**

Our results show that a sandy substrate plays a key role in the expansion of *Sonneratia* forest on tidal flats. In particular, we determine a direct correlation between forest density and percent of sand within the forest fringe. Our data suggest that the river is an important source of sand for the robustness of *Sonneratia* mangrove forests.

We also show that NDVI values calculated from remote sensing images well relate to forest characteristics and, indirectly, to the distribution of bottom sediments. Our remote sensing methodology is therefore useful for the evaluation of ecosystem health as well as to detect prograding areas characterized by sandy bottom sets.

Our methodology can thus be used to map and forecast the evolution of mangrove canopies where Landsat images are available. Finally, our study highlights the impact of sediment availability and characteristics on the health of *Sonneratia* forests, with important consequences for restoration projects of mangroves.

**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.

**PUBLICATIONS**

Nardin W., Locatelli S., Pasquarella V., Rulli M.C., Woodcock C.E., Fagherazzi S. Dynamics of a fringe mangrove forest detected by Landsat images in the Mekong delta, Vietnam (submitted)

Nardin W., Woodcock C.E., Fagherazzi S. Bottom sediments affect *Sonneratia* mangrove forests in the prograding Mekong delta, Vietnam (submitted)