Quantifying the Effectiveness of Previous Marsh Restoration Efforts by Remotely Monitoring Marsh Biophysical Parameters.

Ph.D. Candidate
Department of Earth and Environmental Sciences
University of New Orleans
New Orleans, LA - 70148

Office: GP1013
Phone: 504-280-6681
Email: pdas@uno.edu

Introduction: Research projects or surveys covering emergent wetlands in southeast Louisiana are often limited to marsh habitat delineation and coastal wetland loss analysis. These surveys provide valuable information on the presence/absence of marshes and their change in spatial extent. However, assessment of previous restoration efforts and prioritization of future actions requires more detailed information on marsh condition in terms of its biophysical characteristics. Marsh biophysical characteristics include distribution of chlorophyll content (Chl), green leaf area index (GLAI) (a ratio of green foliage area vs. ground area), green vegetation fraction (VF) (percent green canopy cover), and biomass. These biophysical characteristics are primary indicators of photosynthetic capacity, nitrogen content, and physiological status of marsh vegetation. Monitoring these characteristics through remotely sensed data can help us infer the overall health and productivity of these valuable natural resources on a larger scale so that effective management strategies can be implemented to high priority areas. Although these parameters have long been used to assess the vegetation dynamics in crops, their evaluation and application is very limited in marsh ecosystem studies. While there is little doubt that species diversity factor can be of great importance in planning the restoration, it is the evaluation of the biophysical characteristics that can give significant insight into the marsh vegetation behavior in relation to different external factors such as change in water level, salinity, sedimentation, and elevation etc. The evaluation of these parameters will lead us to better understand the causes behind the periodic events such as "Brown Marsh" event of Louisiana marshes in 2000.

Study Area: The specific study areas include **t**he high priority restoration areas of *Bayou Sauvage National Wildlife Refuge Hydrologic Restoration sites Phase - 1 and Phase - 2 (PO-16 and PO-18) and Fritchie Marsh Restoration site (PO-06)* of the Lake Pontchartrain Basin have undergone restoration activities by the efforts of State of Louisiana Department of Natural Resources (LDNR) between 1996 to 2003 (Appendix 1). A number of surveys have been carried out during the pre- and post construction period until 2007 and future surveys are also scheduled up to the year 2019. The vegetation surveys mainly focus on the species diversity; however, I believe that the incorporation of marsh biophysical characteristics in large spatial scale will allow us to understand the marsh vegetation dynamics precisely. Once successful, I intend to apply my models to the entire southeast Louisiana wetlands.

Goals and Objectives: My primary goal for the present study will be to conduct several *in situ* experiments within the restoration sites (Appendix 1) using hyperspectral fiber optic sensors (Ocean Optics spectro-radiometers) to collect canopy level marsh spectral signature and linking those signatures to the remote sensing satellite data (MODIS and LANDSAT) in order to perform a complete assessment of marsh biophysical parameters (see Gitelson *et. al*., 2008 and Steele *et al*., 2008 for instrumentation design). The hypothesis of this research is that, *changes in marsh biophysical characteristics such as chlorophyll content, VF, GLAI, and biomass is reflected in its spectral signature*. Once the relationship between these ancillary biophysical parameters and marsh spectral signature is established, we can extrapolate that relationship to satellite data to produce various cost effective scientific products. These biophysical characteristics will be mapped in a time-series manner at the specific restoration sites quarterly from 1996 to 2008 (48 maps/12 yrs) and the results will be linked to specific restoration activities during those years. The specific objectives of my study are:

- Measuring marsh chl content, VF, GLAI, biomass at canopy level on the ground and investigating their relationship with marsh spectral signatures acquired from satellite data.
- Develop novel algorithms to map the biophysical parameters from Moderate Resolution Imagine Spectroradiometers (MODIS) and LANDSAT multispectral satellite data.

- Examining the effectiveness of incorporating widely used vegetation indices such as Normalized Difference Vegetation Index (NDVI), Wide Dynamic Range Vegetation Index (WDRVI), and Visible Atmospherically Resistant Index (VARI) in marsh biomass estimation.
- Creation of spatial prototype products such as chl, VF, GLAI, and GPP distribution maps and maps depicting priority areas with the degree of stress level.

My research involves developing algorithms to map the concentrations and spatial distributions of above mentioned marsh biophysical characteristics by field experiments using *in situ* hyperspectral radiometers and extrapolating the results to satellite images. I will perform a comprehensive comparison between the pre- and post restoration marsh biophysical characteristics to assess the effectiveness of the restoration activities in terms of the overall vegetation health. The tangible benefits of my research will include (a) novel map products of spatial distribution of marsh biophysical characteristics such as chlorophyll distribution, VF, GLAI, and biomass within the restoration sites, (b) identification of critical hotspots of marsh stress, (c) prioritization of areas that needs immediate restoration, and (d) assessment of the efficiency of the reference points of present monitoring plan along with the Coast-wide Reference Monitoring System-Wetlands (CRMS-Wetlands) system. ***My work is significant*** because it will allow us for the first time to use satellite data to quantify the effectiveness of restoration activities in terms of marsh overall health in the Pontchartrain Basin. The maps will also serve as baseline datasets for future analyses of habitat restoration, public education, and monitoring activities.

Methodology: My research includes three principal components i.e. field data collection, model development/calibration, and model validation.

***I) Field data collection*:** Field survey will focus on acquiring the following datasets:

- Top of Canopy (TOC) reflectance measurements: This involves marsh canopy spectral data collection by ground sensors (Ocean Optics) for a wavelength range of 400-1100 nm.
- Leaf level reflectance measurements: Both the Ocean Optics and the leaf clip sensors will be employed to collect leaf level spectral signature.
- Leaf level chlorophyll measurement: The SPAD chlorophyll-meter will be used to acquire non-destructive measurements of chlorophyll at leaf scale. The leaf level chlorophyll measurements will be extrapolated to canopy level chlorophyll content.
- Green Leaf Area Index (GLAI) measurements: This biophysical parameter is defined as the ratio of green upper leaf surface area to total ground area. The handheld LiCOR LAI meter will be employed to collect GLAI data at each sampling point.
- Vegetation Fraction (VF) measurements: This is the ratio of green vegetation area to ground area. Digital photographs at each sampling point will be gathered to calculate the VF.
- Biomass Measurements: Within each study sites, six small (20m × 20m) and homogenous intensive management zones (IMZs) will be established. The vegetation in each representative plot will be clipped, put into plastic bags and transferred to the lab for biomass assessment. Total biomass will be determined by weight measurement.
- Digital photographs will be acquired at each sampling point for model validation purposes.

***II) Model calibration*):** Model calibration will be performed based on the relationship between changes in biophysical parameters and corresponding changes in satellite and *in situ* TOC reflectance spectra as follows:

- MODIS and LANDSAT TOC reflectance vs. Ocean Optics TOC reflectance
- MODIS and LANDSAT TOC reflectance, and Ocean Optics TOC reflectance vs. chl, VF, GLAI, and biomass of the marsh vegetation

- MODIS, LANDSAT, and Ocean Optics based vegetation indices vs. chl, VF, GLAI, and biomass of the marsh vegetation

***III) Model validation*):** Model accuracy and sensitivity will be analyzed using an independent biophysical parameters dataset collected on the ground versus the biophysical parameter maps derived from the satellite data. This includes: (1) satellite derived chl distribution map vs. measured chl; (2) satellite derived GLAI distribution map vs. measured GLAI; (3) satellite derived VF map vs. measured VF; and (4) satellite derived biomass distribution map vs. measured biomass.

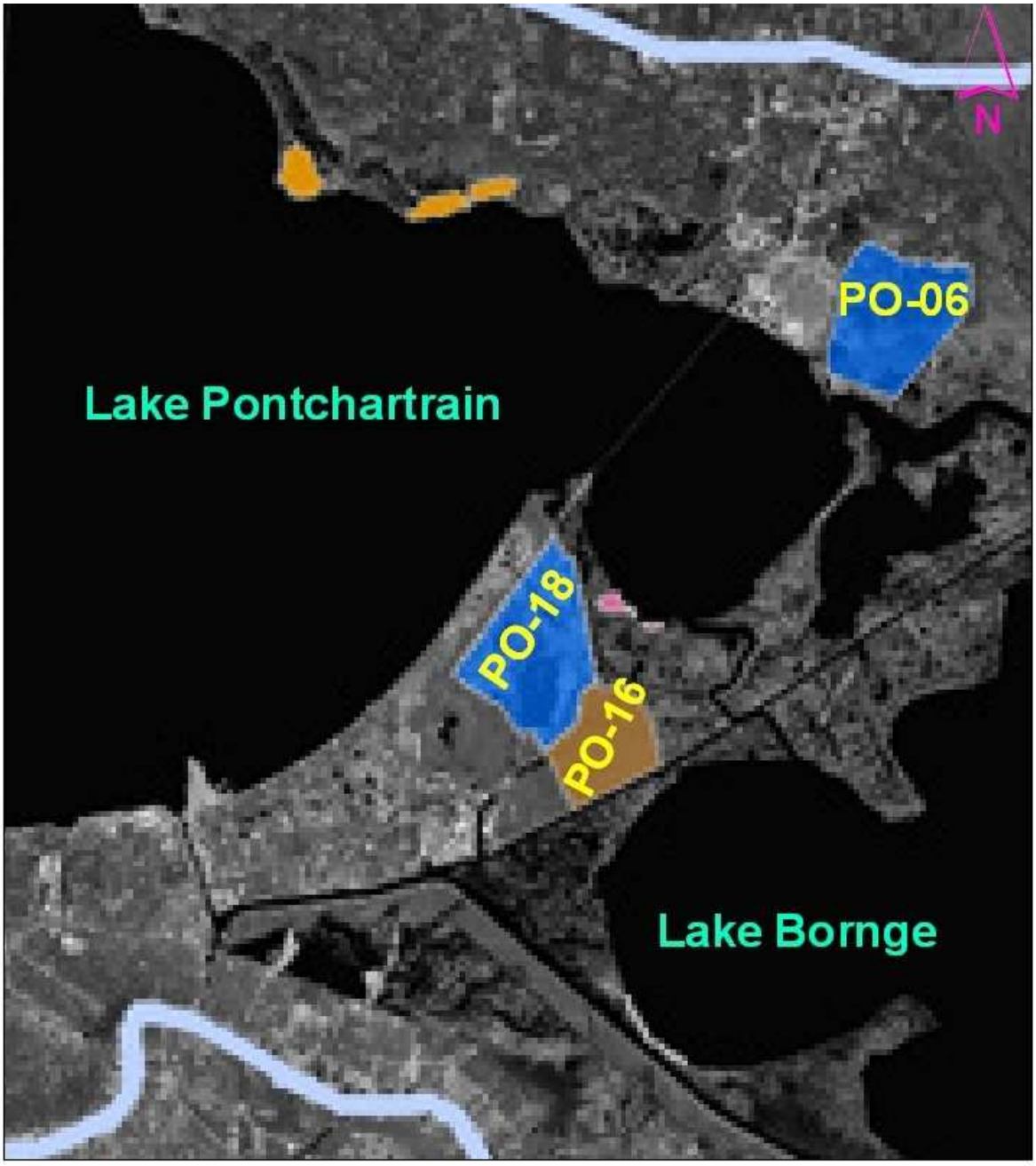
Significance to Wetland Conservation: Although fixed reference system such as CRMS-Wetlands helps immensely on the monitoring front, they need to be evaluated on a timely basis as vegetation has a high spatial and temporal variation in transient ecosystems like marshlands. This will lead to efficient monitoring of the marshes with continuous emphasis on the high priority areas. The identification of the high priority areas can be assessed in relation to the degree of progress, accomplishment, and productivity of different project plans. Monitoring biophysical characteristics of marsh vegetation will allow us to delineate the 'hotspots' of marsh degradation and the reasons behind the degradation which will lead to very successful and effective restoration. It will also minimize the critical data gap that currently exists between marsh mapping and restoration. Analysis of satellite images through remote sensing and Geographic Information Systems (GIS) technologies can help us infer the overall health and productivity of these valuable natural resources on a larger scale. The overall goal of my research is to provide restoration decision makers across the Gulf Coast with a practical tool based on existing NASA products to inform the prioritization of coastal wetland restoration effort and evaluate the success of prior restoration activities.

Personal Statement: Change is the rule rather than exception in nature. So is the case with marshlands. But the greatest puzzle lies in appreciating those changes and the causes behind them. While I carry a strong desire to understand this complex temporal behavioral shifts of wetlands, at the same time I am amazed by their magnificent dynamic ecological balance and survival on such a transitional place on earth's surface which is the confluence point of lithosphere, atmosphere and hydrosphere. This is precisely what drove me to pursue my PhD on the topic of marsh vegetation dynamics in the Department of Earth and Environmental Sciences at the University of New Orleans. Currently I am in the 4th semester of my PhD degree program. After finishing my required course work, I am actively engaged in the field data collection and satellite image analysis. Based on my filed experience, detailed sampling of the three specific restoration sites for each field campaign requires at least 3 people and takes 3 full days. We start the sampling by demarcating six 20×20 m IMZs for each sampling point and acquiring several datasets including reflectance, chlorophyll content, VF, GLAI, and biomass. We assume that the average values of each biophysical parameters for the six IMZs are representative of a MODIS 250 m pixel. This type of intensive sampling requires careful planning and a lot of help from peers. I intend to carry out such field sampling once a month from March/April 2009 to October/November 2009 keeping in mind the phenological characteristics of the marsh vegetation. Therefore, if I am successful in getting the wetland scholarship, I will be spending significant portion of the funds (approximately $4,500 for 6/7 field trips) in field data collection efforts. I would like to spend a small portion of the funds (approximately $500) to attend the 2009 American Geophysical Union (AGU) conference at San Francisco and present my research findings. I am keenly interested to utilize my expertise and knowledge in understanding the marsh vegetation dynamics and developing tools for marsh habitat restoration. My ambition is to work at the forefront of the technology with the ability to find innovative solutions to the changing needs in the field of environmental science. I wish to devote the rest of my career to research and teaching.

References:

Gitelson, A., G. Keydan, and M. Merzlyak (2006). Three-band model for noninvasive estimation of chlorophyll, carotenoids, and anthocyanin contents in plant leaves, *Geophys. Res. Lett.*, 33:L11402

Steele, M., A. Gitelson, and D. C. Rundquist (2008). A Comparison of two techniques for nondestructive measurement of chlorophyll content in grapevine leaves, *Agron. J.* 100(3):779-782



po-16:Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase - 1
po-18:Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase - 2
po-06: Fritchie Marsh Restoration

Appendix 1: Map of the proposal study area delineating specific restoration sites designated by CWPPRA.