PRACTCAL APPLICATIONS OF REMOTE SENSING METHODOLOGIES TO QUANTIFY ENVIRONMENTAL ISSUES FACING COASTAL WETALNDS OF FLORIDA AND PROVIDE CRITICAL INPUTS FOR MITIGATION EFFORTS

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ABSTRACT

Initially, remote sensing methodologies, along with other geo-spatial techniques, were employed for monitoring restoration progress in the Indian River Lagoon (IRL) watershed by the Saint Johns River Water Management District (SJRWMD). These methods were also used in identifying critical habitats in the Guana-Tolomato-Matanzas National Estuarine Research Reserve (GTMNERR). Using no-cost, publicly available digital airborne Color Infrared (CIR) imagery, progress was measured for the restored wetlands in Mosquito River Lagoon of the IRL system. Normalized Difference Vegetation Index (NDVI) was the technique employed. Next, an experiment was conducted to map and isolate the Northern most extent of mangroves (dominated by black mangrove – *Avicennia germinans*) among the emergent intertidal vegetation within the GTMNERR. DigitalGlobe's WorldView-2 (WV-2) imagery was used along with ground-truthed and LiDAR data. In conclusion, this study demonstrated that high resolution multiband (~8-bands) satellite imagery collected at phenologically correct time at low-tide has the potential to quantify the spatial dynamics of this habitat to study the effects of long-term climate change over a period of time.

KEYWORDS: remote sensing, coastal wetlands, Florida, restoration efforts, monitoring

INTRODUCTION

Maps derived from aerial photographs have been used for monitoring the IRL, situated along the east coast of Florida by personnel of SJRWMD. Thematic maps were produced by optical methods using various cartographic techniques. The widespread use of Geographic Information Systems (GIS) was well established by the 1990s, not only to produce thematic layers of various natural resources but also to conduct spatial analysis for monitoring and restoration efforts. Historic, as well as current landcover and seagrass layers were produced by interpreting aerial photographs on a periodic basis. Advanced GIS analysis was performed to calculate the pollutant loadings into the IRL and measure the effects of landcover/landuse changes on seagrass extent, an indicator of water quality in the lagoon.

Remote sensing techniques were not extensively used as large scale photointerpretation was performed regularly producing detailed thematic layers. The district began to procure multispectral data captured by Digital Mapping Cameras such as Intergraph's DMC and Leica GeoSystems ADS40 since about 2005 onwards. The multispectral imagery (RGB & NIR) was used for producing the thematic layers by photo interpretation and heads-up digitization. This process improved the positional accuracy of the layers. A pilot project was commissioned to map the impervious areas using the multispectral data captured by ADS40 sensor. Submerged Aquatic Vegetation (SAV) was also mapped using an airborne hyperspectral sensor system for portions of Saint Johns River. A pilot study was also performed to map seagrasses (both the extent as well as species types) using an airborne hyperspectral sensor. However, these were limited in scope and very expensive. A simple method, the NDVI, proved to be very practical to monitor vegetation recovery on restored wetlands. The only cost involved was the specialist's time and some ground-truthing. High resolution multispectral satellite data with higher radiometry and well defined additional bands proved its potential in mapping the wetlands of GTMNERR.

THE MOSQUITO LAGOON EXPERIMENT

Mosquito River Lagoon is a part of the IRL system that stretches from Ponce DeLeon inlet in the North to Jupiter inlet in the South, a total distance of about 252 kilometers. It is the northern component of the IRL system. Large tracts of highly productive wetlands in the Mosquito River Lagoon were isolated in the 1950s through the construction of dikes to control the mosquito populations. Since the 1990s, many dikes have been removed to connect the isolated wetlands to the IRL system. The elevated dikes are mechanically scrapped down and the ditches are filled appropriately in order to restore the surface to marsh elevation.

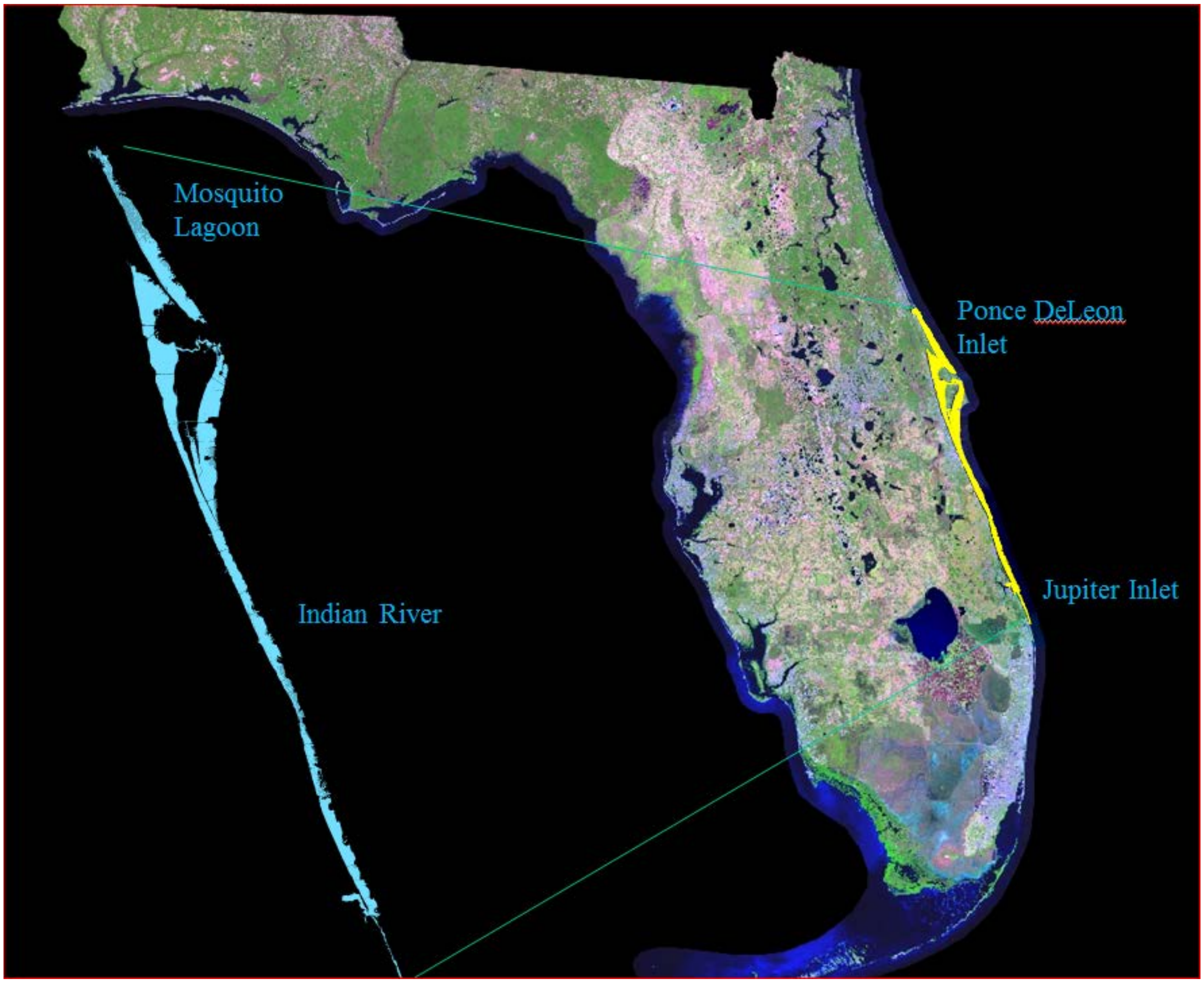


Figure 1. Location of IRL (Florida)

John Rouse of Texas A&M was thought to have first utilized vegetation indices (VI) in the 1970s, shortly after the launch of the first Land Observation Satellite by NASA. The effects of Near Infrared (NIR) & Red reflectance on leaf surfaces is the principle used for VIs.

The dike selected was D12 South in the Mosquito River Lagoon that was progressively restored in 2003, ‘04 and ‘05. Using NDVI techniques (ERDAS Imagine 2010) on the digital aerial photographs, the area of restored vegetation was calculated from 2006-2008. Vegetation gain was also calculated for this period (Table 1). The NDVI technique was simple to use and produced results quickly. Accuracy assessment was conducted using GPS field points in 2008 and ‘09. The results were very encouraging and supplement the field work. In the future, the vegetation trajectory on these restored wetlands could be measured over a long period of time and the success of the efforts quantified. Extensive field work could also be reduced by field sampling methods customized for NDVI.

Table 1. Results of NDVI measurements for D12 South

Area of restored vegetation calculated by NDVI in 2006				
Year restored	Area of dike in Acres	Acres vegetated	Years elapsed	Percent vegetated
2003	10.84	1.03	3	9
2004	5.88	1.92	2	33
2005	16.61	0.51	1	3
Area of restored vegetation calculated by NDVI in 2008				
Year restored	Area of dike in Acres	Acres vegetated	Years elapsed	Percent vegetated
2003	10.84	3.82	5	35
2004	5.88	2.4	4	41
2005	16.61	6.45	3	3
Vegetation gain calculated by NDVI 2006-2008				
Year restored	Area of dike in Acres	Acres gained	Years elapsed	Percent gained
2003	10.84	2.88	2	26
2004	5.88	0.48	2	8
2005-08	16.61	5.94	2	36

ESTUARINE HABITATS MAPPING IN GTMNERR

The GTMNERR is made up various components of relatively undeveloped coastal & estuarine habitat along the northeast coast of Florida, an area of about 30,000 ha. This area, the length of about 64 kilometers is biogeographically positioned at the northern ecotone of the mangrove habitat dominated by black mangroves, *Avicennia germinans*. The vicinity around the city of St. Augustine marks the approximate boundary between the temperate climate to the north and the peninsular subtropical climate to the south. Mangroves are intolerant to freezes and temperature is the primary factor limiting the northern distribution of mangroves (Odum et al. 1982). Black mangroves dominate large portions of the emergent intertidal vegetation in the southern portion. Overall smooth cordgrass (*Spartina alterniflora*) dominates the intertidal habitats (Leitholf 2008). During the freeze of mid 1980s thousands of hectares of black mangroves died but have since recovered substantially and are increasing in coverage. Emergent intertidal habitats form an extensive and direct land-water interface and the effects of climate change and sea level rise impacts them the greatest (Najjar 1990: Scavia 2002: Craft et al. 2009).

Background

The coastal salt marshes are generally thought to have kept up with the sea level rise due to accretion. Thus, the gradual sea level rise was offset by marsh grasses building their substrate on decomposing material and trapping sediments. Accelerated sea level rise however would exceed the rate of accretion for these habitats and would drown them out resulting in extensive loss of these habitats and/or conversion of these habitats to a different type. Sea Level Affecting Marshes Model (SLAMM - Warren Pinnacle Consulting, Inc.) has been used in the IRL system to predict the effects of sea level rise and the potential changes of habitat values by Industrial Economics Incorporated (IEc), Cambridge, MA. The report formed the basis for study done by University of Florida, Gainesville, FL. SLAMM has been used for this study as well.

A landcover map was prepared for the GTMNERR by SJRWMD in about 2007 using heads-up digitization on CIR digital aerial photography and interpreting the vegetation cover. The classification system was unique for the area as the wetland classes were grouped according to the dominant vegetation types delineated by interpreting high resolution digital aerial photography. However that was a onetime effort and the process was time consuming and exhaustive. Some of the wetland classes could not be accurately mapped due to lack of elevation information.

Satellite Mapping – GTMNERR

In 2011, a World View-2 (WV-2) scene was obtained courtesy of 'DigitalGlobe' and '2012 ERDAS IMAGINE DigitalGlobe Geospatial Challenge' (Figure 2). The product was delivered in radiance units after the necessary radiometric corrections to the digital numbers. The date of the imagery was important to capture the maximum variation in phenology.

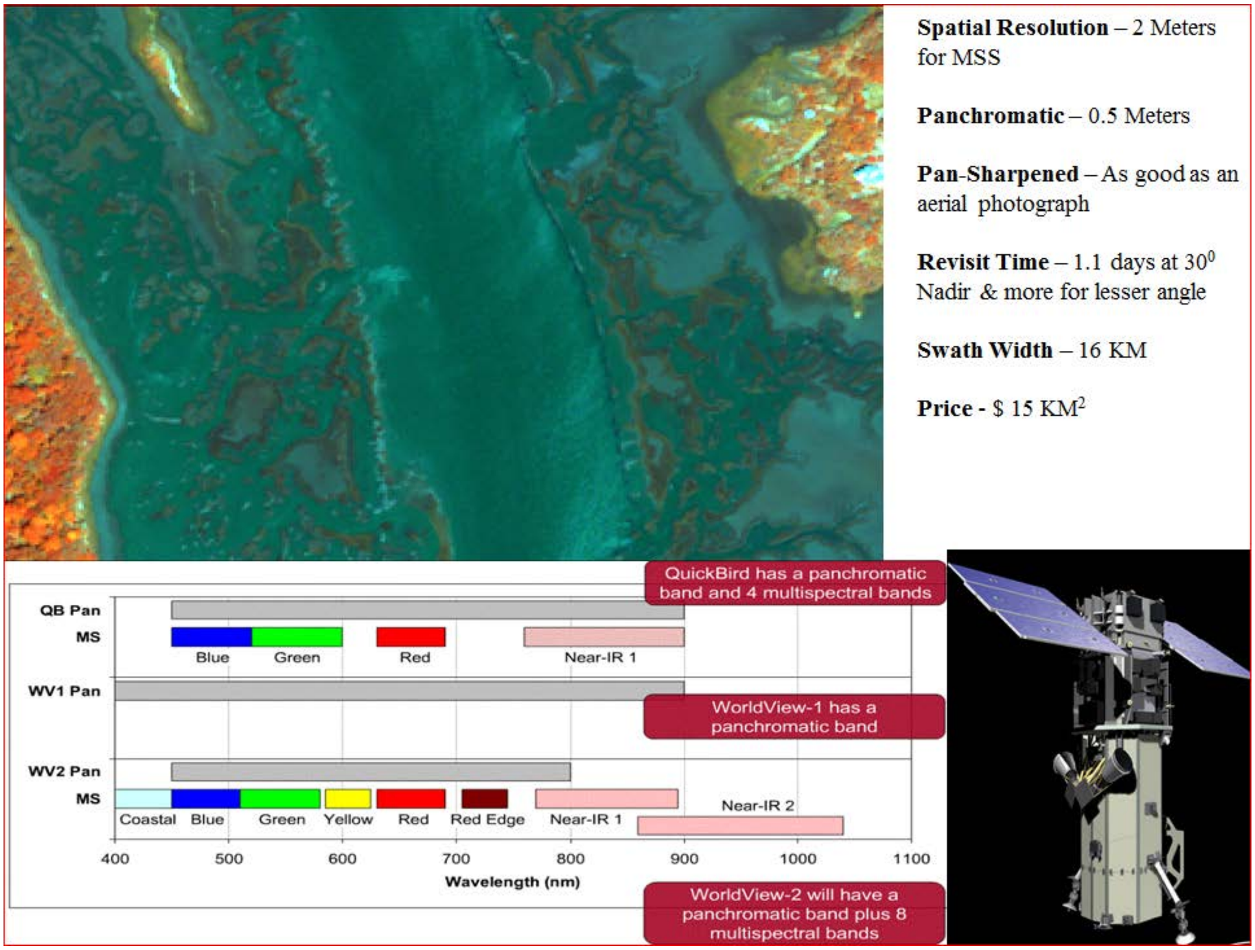
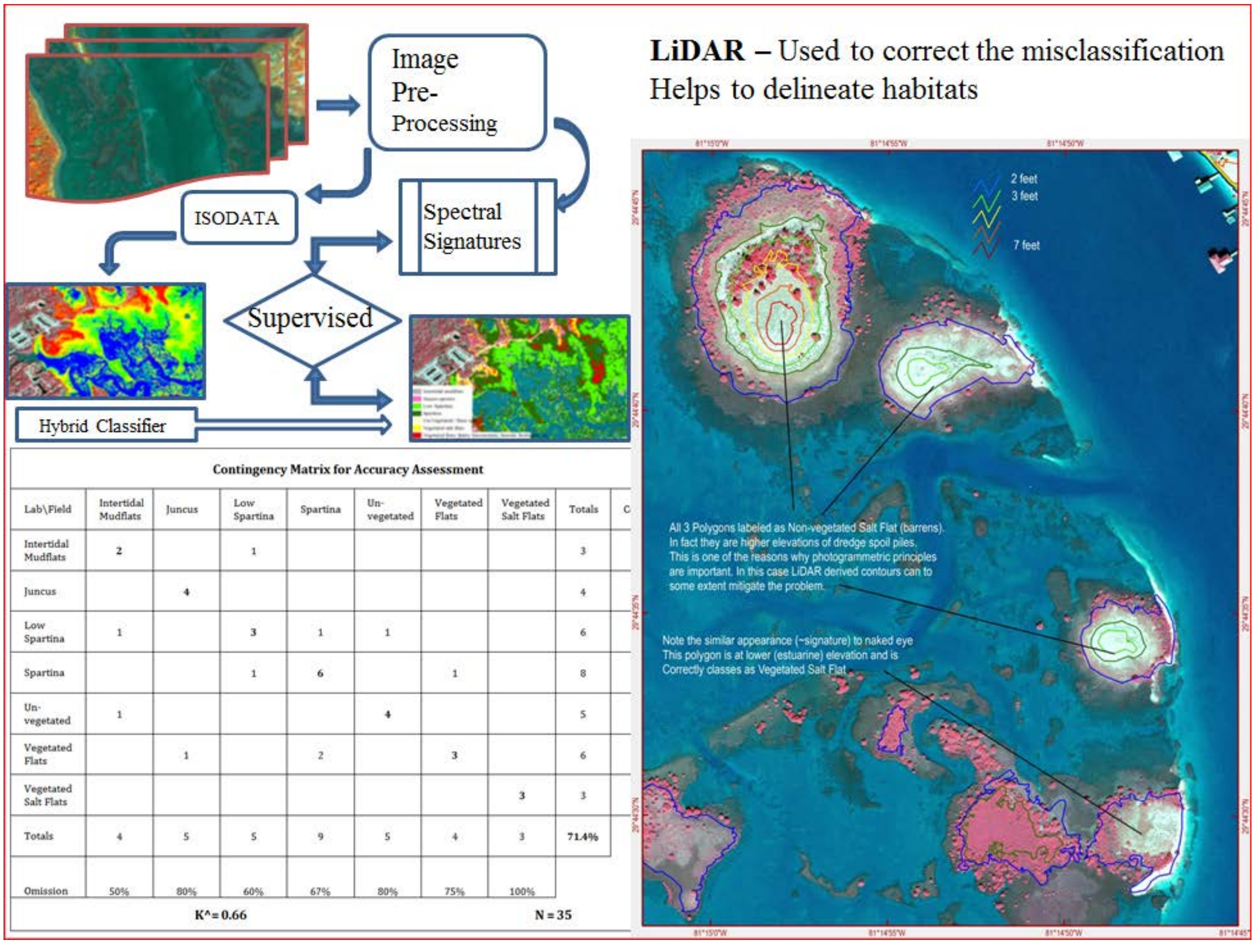


Figure 2. Overview of WV-2 imagery used for this effort including a snapshot within the reserve

The spectral, spatial and radiometric resolution of the WV-2 data makes it ideal for mapping estuarine habitats, including perhaps shallow SAV. The process is automated for the most part and repeatable. The same imagery can be used to map different habitats such as wetlands, uplands, oysters, SAV, etc., using different methods. As in most satellite image classification, the hybrid method is the best. The importance of field work, collection of signatures and ground-truthing cannot be overlooked, as the accuracy of the thematic layers derived depends on these inputs. In addition, LiDAR data could be input to separate the subtidal and supratidal elevations from upland habitats (Figure 3).



Contingency Matrix for Accuracy Assessment

Lab\Field	Intertidal Mudflats	Juncus	Low Spartina	Spartina	Un-vegetated	Vegetated Flats	Vegetated Salt Flats	Totals	C
Intertidal Mudflats	2		1					3	
Juncus		4						4	
Low Spartina	1		3	1	1			6	
Spartina			1	6		1		8	
Un-vegetated	1				4			5	
Vegetated Flats		1		2		3		6	
Vegetated Salt Flats							3	3	
Totals	4	5	5	9	5	4	3	71.4%	
Omission	50%	80%	60%	67%	80%	75%	100%		
		K^= 0.66					N = 35		

Figure 3. Overview of methods used in producing the habitat map and input of LiDAR for refining the process, table showing the results of accuracy assessment included

The classification efforts were successful and the results encouraging (Figure 4). The additional bands along with higher radiometric resolution (11-bit) proved invaluable in deleting the 'tricky' classes that would normally be confused with similar characteristics (graph in Figure 3). The resultant estuarine vegetation classes along with freshwater and upland landcover classes can be input into SLAMM after appropriately cross-walking these to the SLAMM habitat classes. A well-defined and accurate wetland map is not only essential for current studies but also for predicting the transition to other habitats freshwater or upland.

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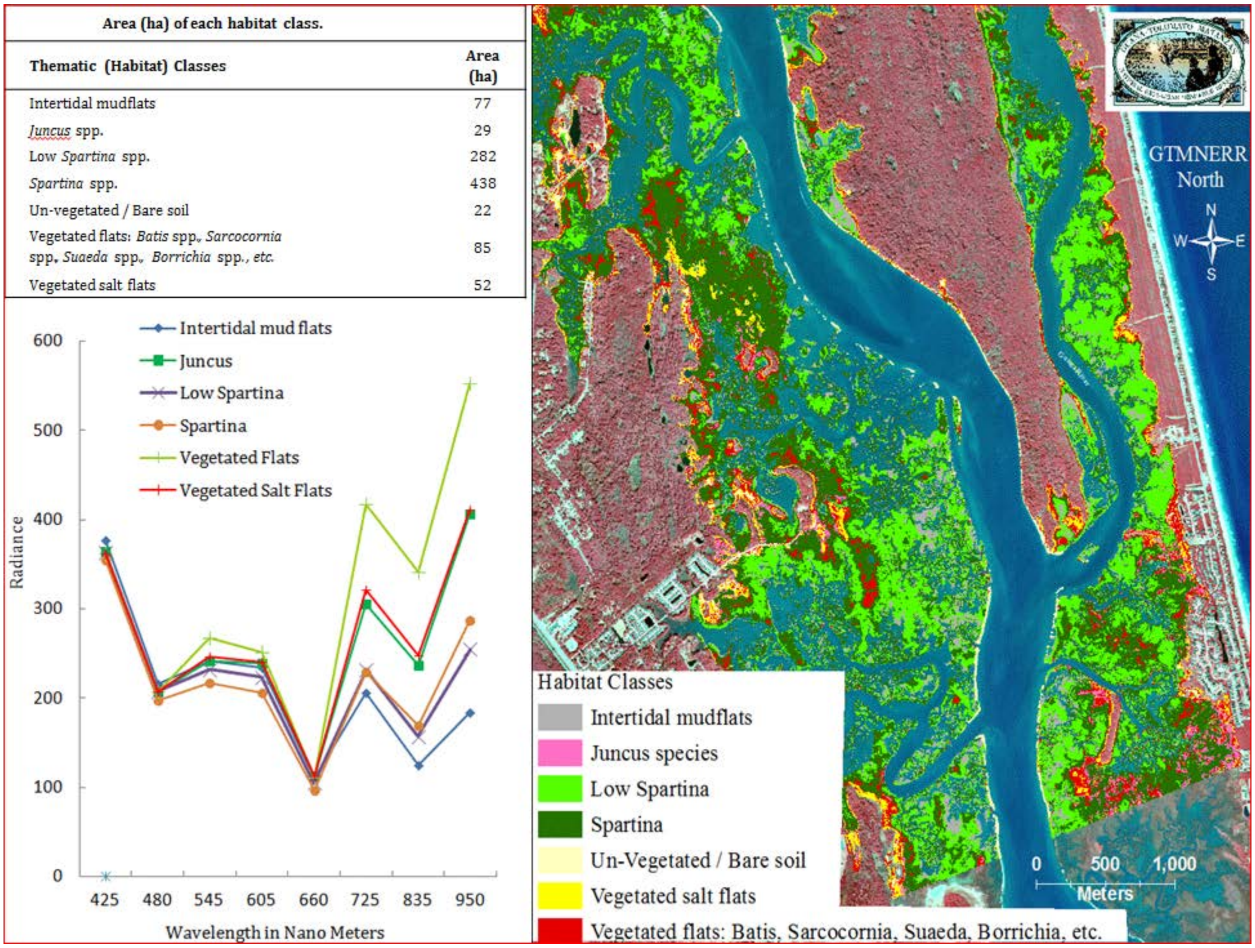

Area (ha) of each habitat class.

Thematic (Habitat) Classes	Area (ha)
Intertidal mudflats	77
Juncus spp.	29
Low *Spartina* spp.	282
Spartina spp.	438
Un-vegetated / Bare soil	22
Vegetated flats: *Batis* spp., *Sarcocornia* spp., *Suaeda* spp., *Borrichia* spp., *etc.*	85
Vegetated salt flats	52

Figure 4. Overview of the results of the classification including the map, breakdown of the area in the table as well as the reflectance of the spectral classes shown graphically

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