MULTISCALE-MULTISENSOR APPROACH IN STUDYING WETLANDS OF THE PARANÁ RIVER DELTA REGION IN ARGENTINA.

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ABSTRACT

The Paraná River Delta Region is a huge mosaic of wetlands which covers 17,000 km^2 at the final portion of the Del Plata Basin in Argentina. This paper focuses on a brief review about how different sensors and a multi-scale approach bring insight on structural and functional features of wetlands, from regional to a specific ecosystem level in a top-down/botton–up approach. At broad scale, ENVISAT Wide Swath Mode (WSM) imagery along with optical SACC-MMRS and the last two decades of Normalized Vegetation Index (NDVI) time series of NOAA-AVHRR satellite systems were used to analyze landscape heterogeneity and wetland functioning in the whole region. The influence of "El Niño" flooding events was evaluated in different wetland landscape units. At fine scale, on the Lower Delta, detailed maps were produced using six Landsat Thematic Mapper images obtaining 28 wetland cover classes with an accuracy assessment of approximately 83%. In this region, special attention has also been given to the study of freshwater tidal marshes dominated by *Scirpus giganteus*. This marsh covers more than 40% of the Lower Delta surface, in the upper portion of the Del Plata Estuary. Net aboveground primary production (NAPP) field measurements were calibrated with NDVI derived from Landsat ETM+ surface reflectance values resulting in the first map of NAPP for the delta marshes. We also addressed the subject of ENVISAT ASAR imagery detecting aboveground biomass variations and water below the canopy.

1. INTRODUCTION

One of the significant features of South America is the enormous extension of wetlands that, considering the size of the continents, are individually and globally the largest in the world. Wetlands occupy in South America about one million of square kilometers.

The largest wetlands in South America are associated with the floodplains of the big rivers (Orinoco, Amazonas and Paraná), and more than 80% of their area belongs to tropical and subtropical humid climate. Some of them extend to the subtropical-temperate zone, like those associated to the Paraná River. The area and permanence of these wetlands depends mainly on superficial water input (by rainfall and rivers water discharge) as well as the timing of the flooding-non flooding cycle [1].

According to these authors, the large wetlands of South America are *macrosystems* of sub-regional extension in which the spatial and temporal variability of the water table constrains biogeochemic cycles and fluxes, promotes soils with strong hydromorphic features, and supports a very rich and particular biota well adapted to a wide range of water availability and hydroperiods.

Compared with other continents, particularly those under temperate conditions, many of South America's wetlands have not been subjected to extreme and massive hydrologic alterations, and thus retain the capacity to support much of the original biodiversity. Grazing has been the prevalent land use. However, the value of wetlands is still not appreciated as it should, and numerous projects that would ultimately reduce their area and biodiversity are planned.

During the last three decades an important amount of data have been acquired by optical remote sensing and, more recently, also, by radar instruments, on different ecosystems of the world. Among optical data sources, we find coarse spatial and fine temporal resolution systems such as 8 km AVHRR data, fine spatial and coarse temporal ones such as TM and ETM+, and systems such as SPOT Vegetation (VGT) and MODIS with intermediate spatial and temporal resolutions. In addition a number of visible, infrarred and thermal spectral channels ranging from multi to hyperspectral are now available. In the microwave region, radar instruments of a single frequency, single polarization (C band: ERS 1, 2 VV SAR, L band: JERS HH SAR), and single polarization, multi-incidence angle (C band, RADARSAT I HH SAR) were followed by ENVISAT ASAR, a multi-incidence angle and dual polarization system. In addition, fully polarimetric data is provided by L-band ALOS PALSAR and in 2007, will also be available RADARSAT 2 C-band data.

This paper presents a brief review about how different sensors and a multi-scale approach bring insight on structural and functional features of wetlands from a regional to a specific ecosystem level in the case of one of the largest wetland regions of South America, the Paraná River Delta.

2. STUDY AREA

The Paraná River Delta (PRD) region stretches through the final 300 km of the Paraná basin. It covers approximately 17,500 km^2, close to Buenos Aires city in Argentina (Fig. 1).

The Paraná river drains an approximate area of 2,310,000 km^2 and, according to its length, basin size, and water discharge, is considered the second most important in South America after the Amazonas. Among the great rivers throughout the world, it is the only one that flows from tropical to temperate latitudes, where it joins the Uruguay river ending in the Del Plata estuary.

The PRD region is a complex flood plain where species of subtropical lineage from Chaco and subtropical rain forest regions, coexist with other species from the neighbouring temperate plains.

According to Malvárez [2], the high landscape heterogeneity of the region derived from the combination of the geomorphologic setting and the hydrological regime, entails a complex of different plant and animal communities that result in a high ecological diversity.

To a great extent, landscape patterns are determined by littoral deposits from marine processes that occurred in the Mid-Holocene (around 5,000 years BP) plus past and present fluvial and deltaic phases.

On the other hand, local rainfall, the seasonal regime of the Paraná and Uruguay rivers, and moon and wind tides of Del Plata estuary differentially affect individual areas.

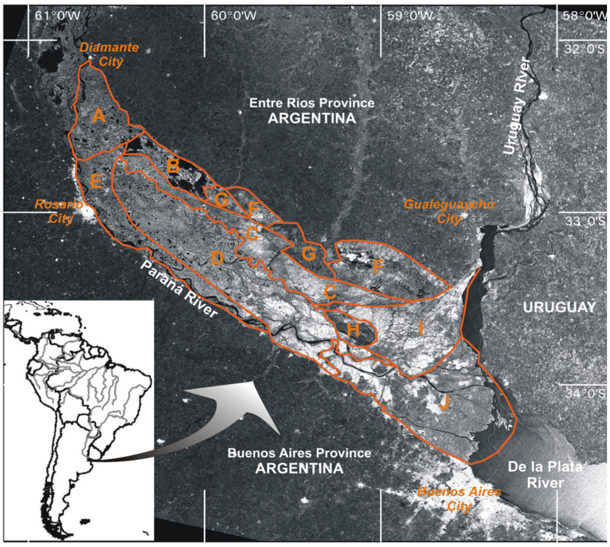

Figure 1. *Paraná River Delta Region and location in South America. A-J indicate Wetland Landscape Units accroding to Malvárez (1997). ENVISAT*

Thus, Malvárez in [2] proposed a classification for this region that include nine wetland landscape units (WLU) based on landscape patterns and the dominant hydrologic regime (Fig. 1) which are described in Table 1.

3. METHODS

Since 2001, the area is being studied through a multiscale-multisensor approach following a top-down/botton-up methodology in order to analyze heterogeneity and dynamic patterns in the Paraná River Delta region (Fig. 2).

At regional scale, ENVISAT Wide Scan Mode (WSM) imagery (pixel size: 75 m) as well as multispectral SACC MMRS optical images (pixel size: 175 m) were used to identify and map the WLUs of the region. Also, long term Normalized Vegetation Index (NDVI) monthly time series of 8km of spatial resolution from

Table 1*. Description of the Wetland Landscape Units (WLU) of the Paraná River Delta Region. From* **A** *to* **J** *as shown in Fig. 1.*

Wetland Landscape Unit	Geomorphic features	Hydrologic Regime	Vegetation (include some dominant or emblematic species)
A	past and actual fluvial	Paraná River	High biodiversity forests/ aquatic prairies of rooted graminoids and broad leaf plants/ open water lagoons
B	past and actual fluvial	Paraná River	Prairies of flooting and rooted aquatic plants (graminoids and broad leaf) / open water lagoons
C	old marine sandy ridges	Paraná River	Marshes / open forests
D	old tidal plain	Paraná River	Prairies of flooting and rooted aquatic plants (graminoids and broad leaf)/ open water lagoons
E	actual Paraná fluvial plain	Paraná River	*Salix humboldtiana* forests / marshes of graminoid plants
F	old litoral lagoon	Local rain	open hardwood forests (*Prosopis nigra*, *P. affinis* and *Acacia caven*) / grasslands / marshes
G	non active deltas	Paraná River	grasslands/ shrublands
H	predeltaic island	Paraná River	Grasslands / Sandy dunes
I	old marine ridges (*cheniers*)	Paraná and Uruguay River	*A. caven* open forests / grassland/ tall marshes (*Schoenoplectus californicus*)
J	active delta plain	Del Plata estuary	High biodiversity (relicts) and *Erithrina crista-galli* native forests, *Salix* spp and *Poplar* spp. afforestations/ tall marshes (*Scirpus giganteus, S. californicus*)

NOAA AVHRR sensor were analyzed within and between WLUs in order to evaluate ecosystem functioning patterns and the influence of "El Niño" flooding events [3].

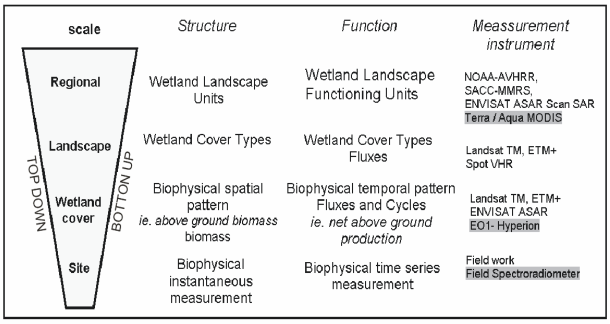

***Figure 2**. Methodological approach*

At Landscape scale, detailed wetland cover maps (WCM) were produced for the southern half portion of the region. Progresive unsupervised classification of six Landsat Thematic Mapper images were performed [4]. The images were selected considering the flood condition and season. At wetland cover scale, special effort has been made in the downstream portion of the delta region, in order to study ecosystem functioning of tidal freshwater marshes dominated by *Scirpus giganteus*. This marsh covers more than 40% of the Lower Delta surface, in the upper portion of the Del Plata estuary and shows a net aboveground primary production (NAPP) of 1514.12 ± 305.11 g m^{-2} $year^{-1}$ (Pratolongo, 2005). A bottom up approach was conducted to map *S. giganteus* NAPP based on a model derived from local field meassurements from 2002-2003 and empirical relationships with NDVI values derived from Landsat ETM+ surface reflectance time series data using [5].
Finally, at site scale, several ENVISAT ASAR copol (VV HH) images were used to analyze above ground biomass and water below the canopy in *Scirpus giganteus* marshes. A paper in this proceedings [6] provides detailed information on the use of radar data in this area.

4. RESULTS AND COMMENTS

Regarding the regional scale, WLUs were clearly drawn on a single ENVISAT WSM HH image according to the presence and spatial configuration of different wetlands types (Fig. 1). In addition, Fig. 3 shows the temporal behaviour of four WLUs along two decades. All WLUs show similar NDVI mean annual maximum, minimum and general trends which follow annual vegetative cycle. Nevertheless, WLUs present differences in inter-annual behaviour. Southernmost WLUs (F, J) present a cyclic behaviour describing annual vegetative periods along the whole time series (Fig. 3). On the other hand, upstream WLUs (units A, B, D and E) show a strong interannual variability since they are more affected by the ENSO events. Nevertheless, the ENSO that occurred in 1982-83 was the only one that shows a significant impact, particularly on WLUs unnconected with the main streams (B, D north).

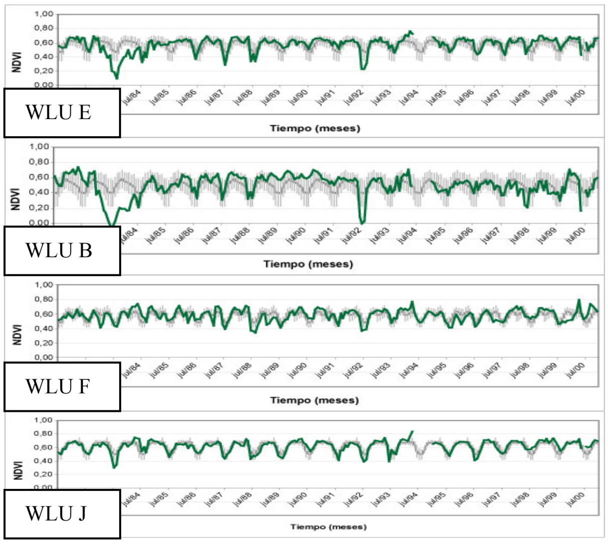

***Figure 3.** NDVI NOAA-AVHRR time series from 1981-2000. Location of* WLUs are shown in Fig. 1. (Source: Zoffoli 2006)

Fig. 4a shows the wetland cover map where 28 wetland cover types were identified. The accuracy assessment of the classification was around 83%. The classification was based on field work data, assuming that landscape heterogeneity derives from geomorphic setting, hydrologic regime, and human intervention [7]. Vegetation and soil characteristics were the primary variables determining spectral signature of each wetland type. The map clearly shows a natural fragmented landscape where man intervention increased the patchiness in some areas (ie. small stands with forestation with salicaceae species, and secondary succession after the abandonement of plantations). In other areas land homogeneization is promoted by large plantation activities, cattle degradation and extensive wood extraction. The wetland cover types map constitutes a critical tool at the time of designing and specifying the limits of the Man and Biosphere Reserve "Delta del Paraná" in 2001.

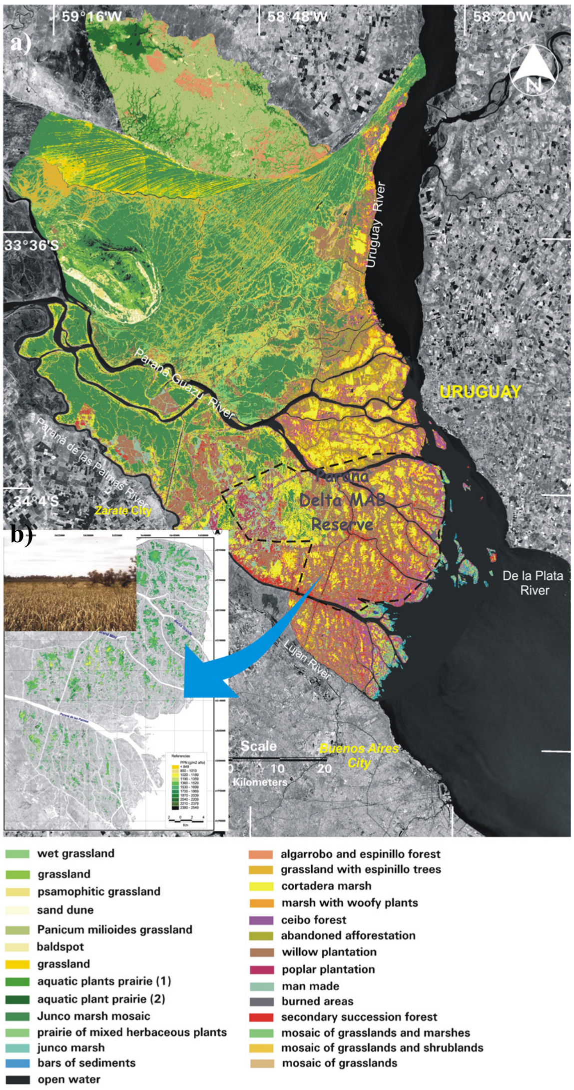

Figure 4. *a) Wetland cover types of the Lower Delta region. (Bono, Srur, Karszenbaum and Kandus 2003). b) Map of S. giganteus NAPP (Pratolongo 2005) Values are biomass in g/m2 produced from Sept.2002 to Sept.2003.*

Fig. 4b presents the NAPP map that clearly discriminates between more and less productive areas which, at local scale, may be related with non floating and floating marshes respectively. At landscape level NAPP map suggests that *S. giganteus* marshes are more productive in the area of influence of the Paraná Guazú river, which is more exposed to sediment input caused by overbank flooding during the El Niño events.

Fig. 5 shows the backscattering coefficient of ENVISAT ASAR S1 (steep incidence angle) and S5 (slant incidence angle) for HH and VV polarization of *S. giganteus* marsh samples. S1 beam mode is sensitive to changes in water level below the canopy, and S5 VV values show differences between spring-summer vs. autum-winter canopy leaves condition.

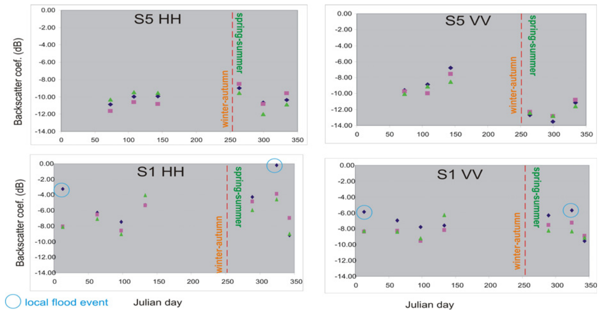

Figure 5. *ENVISAR ASAR backscattering coefficient vs. Julian day in Scirpus giganteus stands.*

Optical sensors of broad spatial scale and short revisit provide unique information about wetland functioning and dynamics. Medium resolution systems are ideal for wetland mapping and for the study of specific ecosystem functioning. The importance of radar data lies on the sensibility to vegetation structure and soil condition providing important information about the water table below the canopy.

This review shows promissing results regarding the combined use of a wide range of instruments in an integrated approach in the PRD region. We conclude that the size as well as the natural heterogeneity and the dynamics of some wetlands of South America present a unique opportunity to explore wetlands ecologycal structure and functioning through a top-down/ bottom-up multisensor-multiscale approach.

5. REFERENCES

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