Monitoring Paraná River wetland dynamics using MODIS NDVI time series

M. Salvia (1), P. Kandus (2), F. Grings (1), H. Karszenbaum (1)

(1) CONICET - University of Buenos Aires -
Institute of Astronomy and Space Physics
REMOTE SENSING GROUP

(2) San Martin University
Instituto de Investigaciones e Ingeniería Ambiental (3iA)
LABORATORIO DE ECOLOGÍA, TELEDETECCIÓN Y ECOINFORMÁTICA

Framework

The largest wetlands in South America are associated with the floodplains of the big rivers like the Paraná.

These wetlands have subregional extension mostly covered by herbaceous vegetation and showing a high spatial and temporal variability of the water table that constrains biogeochemical cycles and fluxes, and supports a very rich and particular biota, well adapted to a wide range of water availability and hydroperiods. Paraná River wetlands are important habitat sustaining commercial fisheries, cattle ranching and apiculture providing also roughness surfaces for flood regulation.

There is a vast history of using NDVI for the study of vegetation characteristics, including biomass, type and condition of vegetation (Lauver y Whistler, 1993, Jensen, 1996). However, the examples on wetlands are few and recent. Zoffoli (2006) analyzing a 20 years AVHRR-NDVI series of the Paraná River Delta Region, could identify the annual and interannual variations of landscape units and their relation with flood pulses. Unfortunately, the low spatial resolution of the sensor did not allow the author to differentiate the productivity patterns of the distinct vegetation types present on the region.

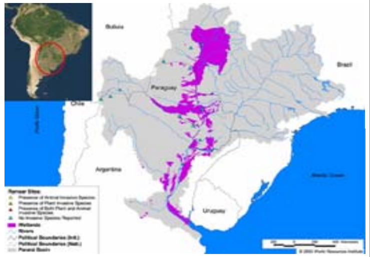


Fig 1. Paraná River sub-basin and Paraná River Delta.

Objective, data and methodology

The objectives of this work were:

- **to identify spatial and temporal change patterns based on the hydrologic and plant phenology behavior**
- **to gain insight on the impact of extreme hydrological events (EHE) on the river floodplain.**

DATA: TERRA-MODIS 13Q1

(NDVI, 16 day composite, 250m)

2000-2008 – Tiles: h12v12 and h13v12

Methodology

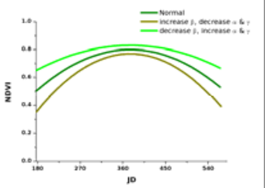
We modeled NDVI temporal evolution as (de Beurs & Henebry 2005):

$$NDVI = \alpha + \beta\, JD + \gamma\, JD^2$$

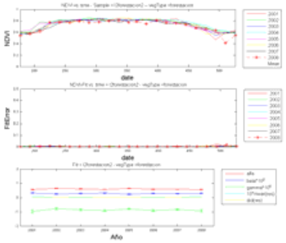
This is a quadratic model of NDVI change along the year, starting in winter, so it coincides with the growing cycle.

The advantage of this model is that it's complex enough to provide a good fit, and simple enough so that each parameter have an immediate ecological interpretation.

Parameter	Definition	Biological meaning	Comment
α [NDVI]	Intercept NDVI pattern	Amount of green biomass at the beginning of the observation period (winter)	Always a positive value between 0 and 1
β [NDVI/day]	Initial slope of NDVI pattern	Initial vegetation growing rate or green biomass uptake rate	Always a positive value
γ [NDVI/day^2]	Concavity of NDVI pattern	Larger absolute values imply shorter growing seasons	Always a negative value



Results

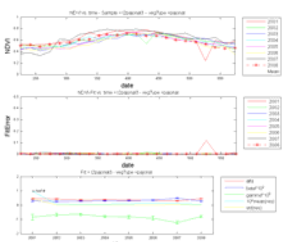


Implanted Forest – no EHE:

1) NDVI patterns show seasonal variations with maximums over summer. Low interannual variability.

2) Parabolic model fits data – very low residues.

3) Model parameters (α,β,γ) values do not show significant variations.

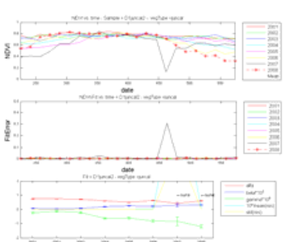


Marsh – no EHE:

1) NDVI patterns show seasonal variations with maximums over summer. Interannual variability is larger than the one of implanted forest, but of the same order than native forests.

2) Parabolic model fits data with very low residues, except for 2001 (sensor failure produced bad data).

3) Model parameters (α,β,γ) values show variation, but these variations are not significant.

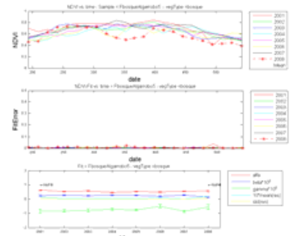


Rush – flooding and drought:

1) NDVI patterns show seasonal variations with maximums over summer. Interannual variability is larger than the one of forests (implanted and native) and marshes.

2) Parabolic model fits data with very low residues, except for 2007 (flooding) and 2008 (drought). In the first case we see an abrupt descent of NDVI and a rapid recovery of previous values when the water starts receding (1 month). In the second case there's a gradual descent of NDVI as plants wither.

3) From 2003 to 2006, α and γ decrease and β increases. This leads to a more extreme seasonality.

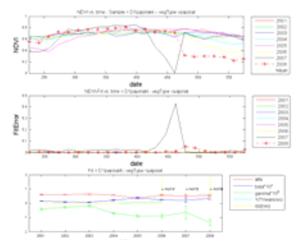


Forest – drought:

1) NDVI patterns show seasonal variations with more interannual variability than implanted forests.

2) In years when parabolic model fits data, this interannual variability is seen in the values of model parameters (α,β,γ).

3) Model does not fit in 2001 (due to sensor failure that produced bad data) and 2008 (due to a regional drought).

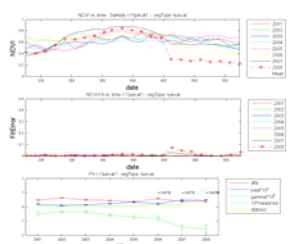


Marsh – flooding and fire:

1) NDVI patterns show seasonal variations with maximums over summer. Interannual variability is larger than the one of implanted forest, but of the same order than native forests.

2) Parabolic model fits data with very low residues from 2001 to 2006. In 2007 this sample was affected by a flooding related to an ENSO event, and in 2008 by a fire. In the first case, there is a progressive and rapid descent of NDVI value as the site got flooded, and a rapid recovery as the water receded. In the second case, there is a rapid descent as the vegetation got burned, but no recovery at least until the end of that winter.

3) From 2003 to 2006, α and γ decrease and β increases. This leads to a more extreme seasonality.



Rush – fire:

1) NDVI patterns show seasonal variations with maximums over summer. Interannual variability is larger than the one of forests (implanted and native) and marshes.

2) Parabolic model fits data with very low residues, except for 2008 (fire). In this year we see an abrupt and persistent descent, as vegetation cover was almost completely burned in April 2008, and did not start recovering until the end of that winter.

3) From 2003 to 2006, α and γ decrease and β increases. However, this difference in parameters was not significant.

Conclusions

- For undisturbed implanted forests, the parabolic model provides a good fit, like an undisturbed terrestrial land cover type, and the stability of its parameters accounts for the stability of these ecosystem's productivity patterns.
- Native forests are also ecosystems with stable productivity patterns, although with more variability than implanted forests . This greater variation in NDVI can be explained by: (1) the presence of different tree species with distinct productivity patterns within the same ecosystem, (2) a greater degree of anthropogenic disturbance (i.e. selective logging, grazing of the understory) and (3) susceptibility to environmental events (floods, droughts, etc).
- Herbaceous vegetation communities generally show productivity patterns with greater variability than native or implanted forests, that is reflected in a more frequent rupture of the parabolic pattern and in changes of its parameters. The higher interannual variability can be explained by: in years of non parabolic patters (1) a grater degree of anthropogenic disturbance and (2) a larger susceptibility to environmental events (flood, droughts, fires), and (3) herbaceous vegetation's adaptability to local environmental changes (i.e. yearly nutrients and water availability) in the case of model parameters variation.
- As for events that break NDVI parabolic pattern, flooding usually cause sudden drops and short recovery times of the signal, after which previous values are recovered. This behavior distinguishes this kind of events from droughts and fires, however, it is the same effect found in case of erroneous data, be it by sensor malfunction or cloud effect.
- Drought and fire events can be differentiated from the flooding given the fact that the recovery of original NDVI values is more gradual, taking a longer time. Even when distinction between these two types of events is harder, fires usually show a quicker drop of the signal, while this descent, in case of droughts is usually more gradual.

Future work

We are currently working in mapping and classifying the parameters of the model used for the sample analysis, in order to compose a map that considers both the land cover type and its annual and interannual dynamics.