EVALUATION OF CHANGES IN ATLANTIC FOREST (VALLEY OF CUÑA PIRU, MISIONES, ARGENTINA) WITH MULTI-TEMPORAL SATELLITE DATA.

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ABSTRACT:

The forest in the province of Misiones, northeastern of Argentina, is a portion of Paraná Forest (or Atlantic Forest) located also in the south of Brasil and Paraguay. At the beginning of the last century the native forest had an extension of more than 100.000.000 ha. Actually, Brasil preserves only the 5% and Paraguay the 10% very spoiled and fragmented. In Argentina the decrease was the 45%, and keeps in existence 1.422.661 ha (National Forest Inventory 2003), with the higher values of biodiversity of the country. This area in Argentina has an accelerated rhythm of urbanization and deforestation. The productive system in the zone provides between 70% to 85% of wood to national market. Recent studies of diversity and dynamic of the native communities are very limited. For these reasons it's necessary to increase the spatial information of the natural resources, the expansion of human activities and the disturbances in the environment to improve the management, the arrangement of territory and the tools for the decisions makers. The main objectives of this study were: to analysis spatial and temporally the structure and dynamic of forest in the Valley of Cuña Piru (sector of Atlantic Forest, Misiones), and to compare different methods and tools in order to develop an efficient and operative methodology for a systematic monitoring of the status/condition of the area, by mean of satellite images analysis (Landsat and Aster) and GIS techniques (modeling, mapping of changes, identification of plants structures and physonomy by different classification methods). The preliminary results showed an operative and efficient methodology with remote sensing tools for the forest monitoring and a preliminary protocol of processes was developed.

1. INTRODUCTION

The Interior Atlantic Forest (SAI), called, in Argentina, Selva Paranaense or Misionera, extends along the east coast of Brazil, east of Paraguay and northeast of Argentina (Cabrera 1976, Olson & Dirnerstein 1998).
As other natural systems, has suffered a sharp decline during the past century and nowadays survives only the 5% in Brazil, and 10% in Paraguay of the 100 million existing hectares in early century, mostly in a highly fragmented and deteriorating way(Holz & Placci 2003). In Argentina, the reduction was near 45%, leaving a remnant of 1.422.661 ha natural forests (Montenegro et al. 2002), concentrating here, the National greatest biodiversity (Zuloaga et al. 1999). Despite this, the SAI of Argentina is one of the least studied forests units of the country and with the most accelerated rate of urbanization and deforestation (Arturi et al 2005). This situation stands out the needs to increase spatial information, both in resources as in human disturbance activities in order to develop appropriate criteria for land use management.
Focusing mainly on the length of studied area, the tropical forest coverage mapping and its monitoring, can be accomplished by applying remote sensing and geographic information systems (GIS) (Freeman & Fox 1999).
Despite the emergence of new sensors, the MSS/TM Landsat images remain to be useful. These images cover a 30 years period that allows a clear analysis of tropical forest changes. There are many examples in this regards: PRODES Project of the National Space Research Institute (INPE) of Brazil that monitors the amazonian deforestation evolution since 1973, such as Skole & Tucker (1993) researches exploring the relationship of Amazon deforestation rate and its interference with climate change, Vieira et. al . 2003, Lu et.al. 2003 , who develope classification methods for Amazon vegetation units mapping by using Landsat; Hansen et.al . (2001), Gautman et.al (2003), Fronsini de Barros Ferraz et.al (2005) whose researches are based on landscape dynamics of forests deforestation and fragmentation by applying Landsat; among others.
The present study analyzed the SAI Laurel-Guatambú forest and forested land changes in Cuña Piru Valley, Misiones, and its environs, from 1973 to 2007 with MSS/TM/ETM+ Landsat, and ASTER sensors; and GIS techniques. The main objectives of this study were: to analysis spatial and temporally the structure and dynamic of forest in the Valley of Cuña Piru (sector of Atlantic Forest, Misiones, Fig.1), and to compare different methods and tools in order to develop an efficient and operative methodology for a systematic monitoring of the status/condition of the area.

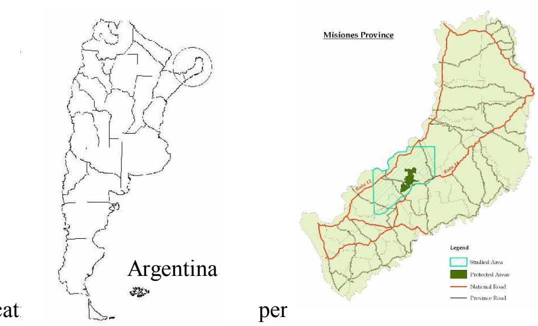

Figure1. Location of Study Area

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2. MATERIALS AND METHODS

The materials used in this work were:
- Landsat images: MSS, TM and ETM+ from February 1973 to February 2007, and Aster image (2003); visible, near infrared and SWIR (short wave infrared) bands.
- Topographic maps (2754-19 and 2754-20-I), from the Militar Geographic Institute (IGM),
- Digital Elevation Model (DEM (90m), from NASA-SRTM,
- Field data, to collect the structure, spatial arrangement and plants composition of the forest.
- Softwares: ERDAS Imagine 9.0, Arcview 9.1, Idrisi, ENVI, and statistics tools.

The work was divided in five steps:
a. Standarization of satellite data: several factors have influence in quantification and qualification of solar radiation reflected when different sensors are used along time. The main sources of error for identification of physonomic-estructural changes in vegetation among dates are: atmospheric conditions, errors in image registration, topographic effects, sensor variability, the abundance, composition and phenological condition of vegetation. This step included:
a.1. Atmospheric correction: it was evaluated three methods of ¨Dark object substraction¨ (DOS1, DOS2, DOS3 and DOS4) 1234) (Chavez,1988; Song et al., 2000) and one of ¨Dense Dark Vegetation Approach¨ (DDV) (Kaufman et al.,1988).
a.2 Geometric correction (georeferentiation): all the images were co-registered from a Landsat TM 224/79 August, 1989 of the University of Maryland. (resampling method: cubic convolution, RMS less than one pixel, cartographic projection system: UTM (WGS84), zone 20 South).

b. Generation of forest maps: a first categorization of vegetation from the field data and satellite images processing was carried out. The categories considered and its descriptions were:
- Capuera: cane with small trees (height: 5m).
- Grassland: grassland (50-75%).
- Savannah with trees: grassland (50-75%), bare soil (0-20%), trees (10-25%, Urunday: *Anadenanthera colubrina).*
- Capuerón with one trees layer: cane with trees (height 15m), dominant species: *Helieta apiculata, Trichilla catigua, Nectandra spp, Ocotea spp., Lonchocarpus leucantus, L. muehlbergianus.*
- Capuerón with two trees layer: understorey species, cane, first trees layer: 20m, second trees layer: 15m, dominant species: *Nectandra saligna, Diadenopterix sorbifolia, L. muehlbergianus, L. leucanthus, Luhea divaricata, Helieta apiculata, Trichilla catigua, Allophylus edulis.*
- Mixed Forest in low land: dominant species: *Helieta apiculata, Nectadra spp. Patagonula americana, Bolfourodendron redelianum, Holocalyx balansae, Parapiptadenia rigida, Rupechtria laxiflora.*
- Forest in high land: dominant species: *Apuleia leicocarpa, Enterolobium contorstiliquum, Tabebuia spp, Cedrela tubiflora.*
- Grove:dominant species: *Helieta apiculata, Nectandra spp, Acacia spp., Chorisia speciosa, Melia azedarach*
- Implanted forest: exotic species: *Aleuritis fordii, Melia azedarach Pinus spp,*

In order to apply the mapping methods to wide scale, the forest units of the first categorization were grouped into five classes: -
- Dense High Forest (MAA)
- Sparse High Forest (MAD)
- Low Forest (MB)
- Capuera
- Implanted forest

c. Generation of models of natural and human variables in order to interpret the spatial distribution of plant communities and predict its location in areas with difficult access. In this point we generated two predictive models: one with natural variables (height, slope, aspect, NDVI, etc) and other with human variables (distance to: rivers, villages, roads, etc.). These models were compared with the forest maps, and statistical analysis were carried out.

d.Development of a methodology for multi-temporal comparison of forest: the images were grouped by date in summer and winter set data. Different classification methods were evaluated to separate forest vs other covers as the following:
- MCVT: Variance classification from application of texture filters.
- CnSI: Unsupervised classification (ISODATA).
- CnSIcp: Unsupervised classification (ISODATA) from PCI results.

After the selection of the best method, we follow with the classification of different type of forest (with the same categories of the forest maps). The methods evaluated were: SAM, ISODATA, Maximum likelihood, PCI, Tasseled Cap, NDVI with several combination among the individual results of each process.

e. Multi-temporal comparison of natural and implanted forest: this comparison was carried out by Change detection method among best classified images (previous point). Also, the NDVI differences were analyzed, and both results were integrated.

3. RESULTS AND CONCLUSIONS

We can generate a methodology (a protocol) of standarization of data satellite of different dates and sensors.
The analysis showed that the DOS2 model of atmospheric correction (Chavez,1988; Song et al., 2000) was the more adequate for the study area. The details of the geometric correction process were as appear in materials and methods.
It was possible from de satellite and field data analysis to elaborate the forest maps to work in two scale of details.
In the Figure 2 we can see the forest map with nine units of vegetation in the area of Cuña Pirú Reserve with more details than we can observe in the Fig. 3 where are represented only four forest classes, while the plantations, the agricultural uses, grassland, settlements are grouped as unclassified en the Fig.3.
The methods to generate this last forest map can be used in other areas near Cuña Pirú Reserve to separate forest vs non

forest along the time, they are maps comparables to different scales. The more accurate classification method used in the generation of these maps was the algorithm Maximum Likelihood (with Kappa coefficient =0.87) (Figure 3).

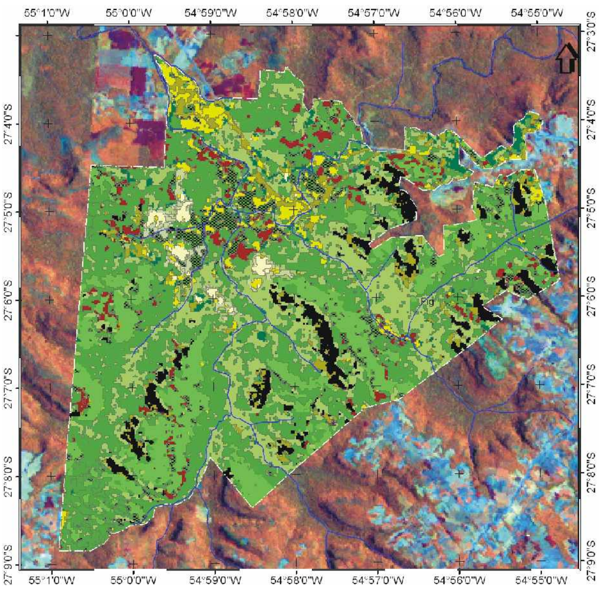


Figure2. Forest Map of Cuña Pirú Reserve with nine units: green tones are different forest(six units),light green-ecotonal zone, beige-sacannah, yellow-grassland, black-shadow

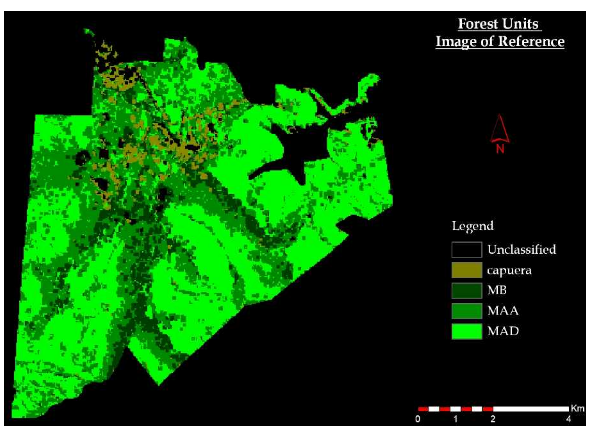
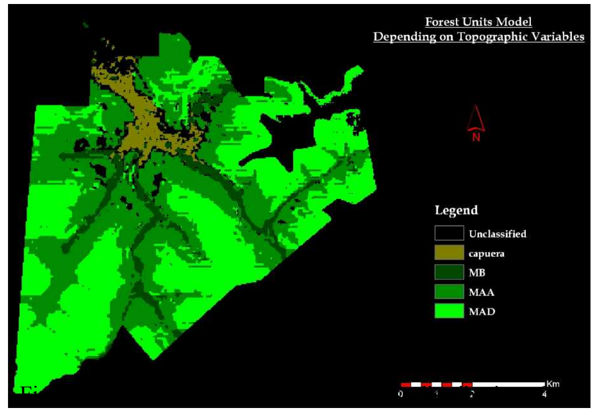


Figure 3. Forest Map of Cuña Pirú Reserve (four forest units). Supervised classification of Landsat TM February 2007.



topographic variables.

The elaboration of a model of native forest of Cuña Piru zone from topographic variables was obtained. It explaines the 60% of the spatial distribution. The results of this model are preliminary. The Figure 4 shows this model, that if we compare it with the Figure 3 we can suggest that the units in the model have similar distributions than in classified satellite image.

The best process in order to separate forest vs non forest was CnSIcp for MSS data (Kappa coefficient 0.88-0.85) and CnSI (Kappa coefficient 0.87-0.83) .

An effective comparison between the different forests and land use (agricultural and livestock) and the changes of the last 30 years were detected, for example as shows the Figure 5, the native forest decreased 23% (435 ha) from 1976 to 2007.

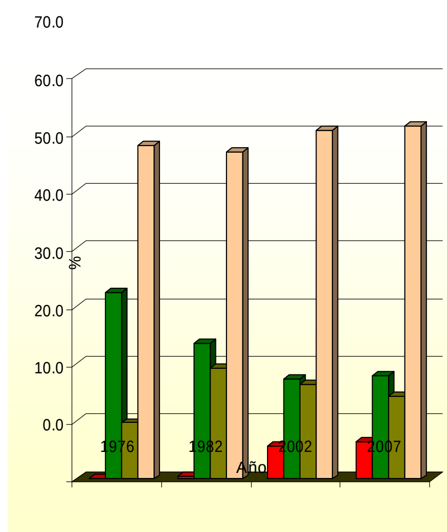


Figure 5. Changes along time of different covers: beige=other covers, green= native forest, red=plantations.

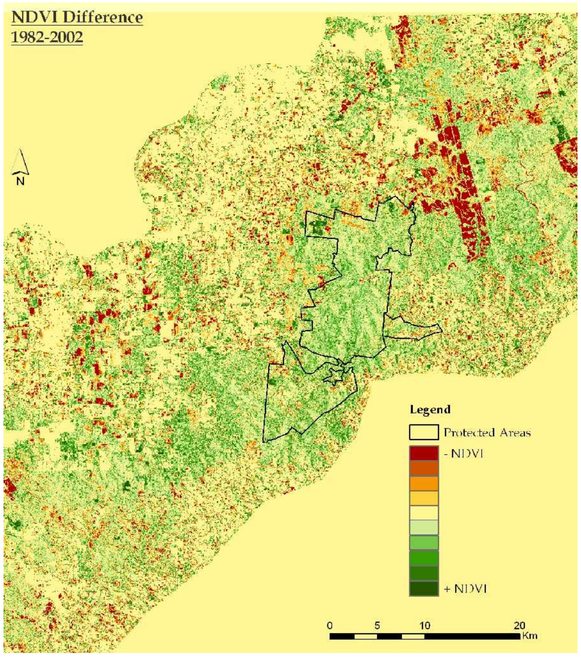


Figure 6: NDVI Difference between 1982 and 2002, in red decrease, in green increase.

In the Figure 6, as example, we can observe the changes along time and space, considering the variations in the NDVI values.

All the processes that we have tested and combined in this study gave us interesting results and many times they are the origin of future researches in this thematic.

Many statistics results and processed images can not be presented yet, but they are very promising.

We considered that our preliminary results constitute the beginning of tools set for the entities public and private, and non-governmental organizations to improve the sustainable management of natural resources and preserve this important region with the higher values of biodiversity of our country.

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