

## YUNGAS CHANGE DETECTION USING LANDSAT TM IMAGERY FOR LAS JUNTAS, CATAMARCA, ARGENTINA

Analia Isabel ARGERICH<sup>1</sup> ; Juan Rodolfo BARROS<sup>2</sup>

<sup>1</sup> Director of the LatinGEO Argentina (Laboratory of the Geographical Information Technologies), National University of Catamarca - Faculty of Technology and Applied Sciences -

Maximio Victoria 55 – (4700) Catamarca – Argentina – TE +543834437186 Int. 141 –  
Fax +543834437186 – Email: [anargerich@tecnounca.edu.ar](mailto:anargerich@tecnounca.edu.ar)

<sup>2</sup> Professor and researcher biologist. National University of Catamarca - Faculty of Natural and Exact Sciences -

Avenida Belgrano 300 (4700) Catamarca - Argentina- TE +5493834761139 – Fax +543834437186  
Email: [juanrb\\_568@yahoo.com.ar](mailto:juanrb_568@yahoo.com.ar)

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**ABSTRACT:** The ecoregions of montane forest which are found in South America and along the eastern slope of the Andes Mountain Range, from approximately 08° North latitude -in Venezuela- to 28° South latitude -in Catamarca, Argentina-, are called Yungas.

It is known that the Yungas' ecoregions present unique environmental conditions for the development of biodiversity, playing a key role in the water collection function, since the regional production systems of the lowlands depend mostly on the irrigation provided by the Yungas.

In Argentina, the Yungas come in from Bolivia, adopting the form of a narrow strip of less than 100 km wide, along 600 km in a North-South direction, through the Provinces of Salta, Jujuy, Tucumán and Catamarca, with altitudes that vary between 400 m and 3,000 m above sea level.

The Yungas' dynamics in Catamarca has not been studied in depth yet, thus, a pilot area corresponding to the sub-basin of the Las Juntas River has been selected, with the purpose of analyzing the modifications experienced and determining if they are associated with the regional process of expansion of forests stated by different authors.

Based on Landsat TM images -years 1998 and 2010- provided by CONAE (Argentine National Commission of Space Activities), this work compares the surfaces covered by Yungas in the area under study, analyzing their dynamics in a 12-year period. The processing of the Landsat images -with Idrisi and GvSig software- allows verifying that the montane forest -with its most representative species in Catamarca: *Podocarpus parlatorei*- has increased spatially in a 100% and evidences a greater vegetal strength, which constitutes a promising fact for the purposes of the biodiversity conservation.

### INTRODUCTION

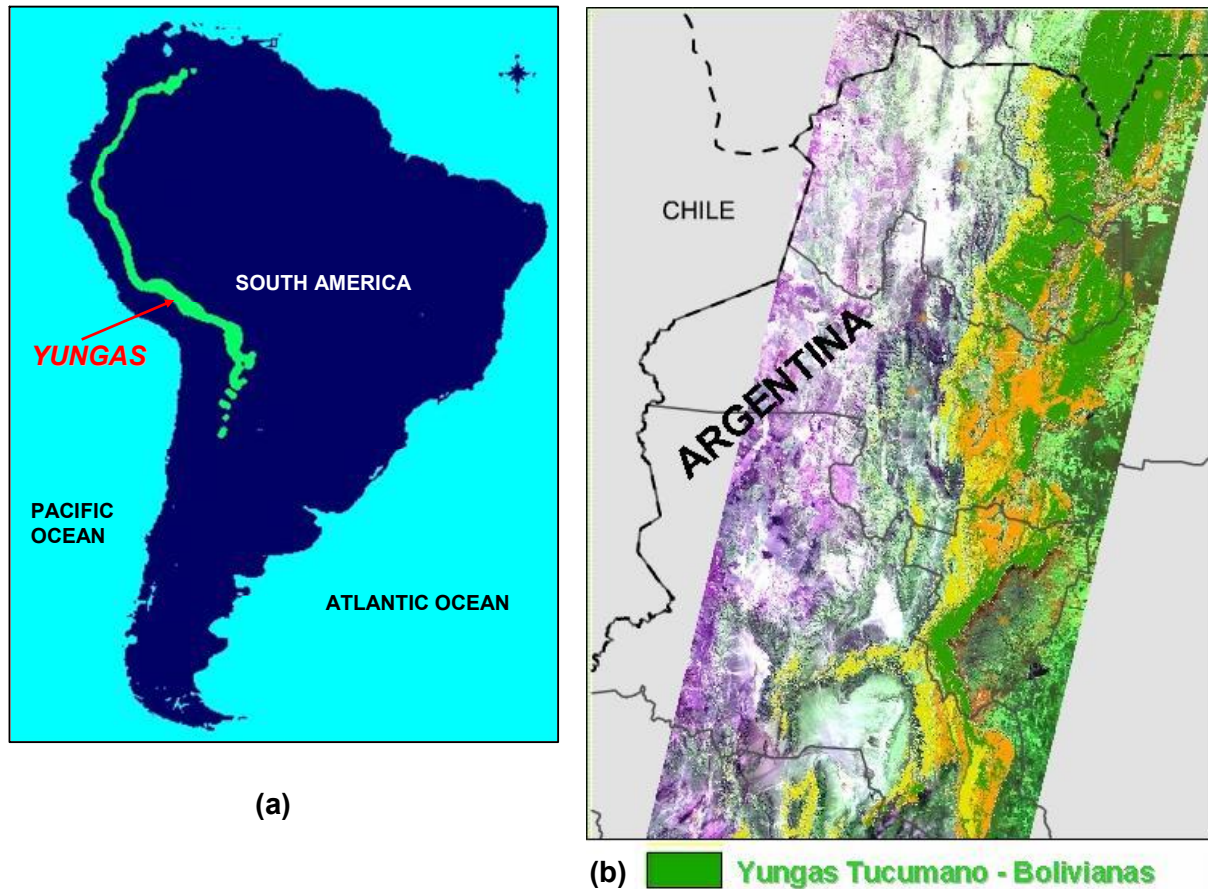
The Yungas' ecoregions constitute a phytogeographic formation extending from approximately 08° North latitude -in Venezuela- to 28° South latitude -in Catamarca, Argentina-, adopting the form of a relatively narrow strip (Figure 1). Their main characteristic is the presence of rainforest vegetation -montane forest and also, Andean forest- which develops in mountainsides, valleys, gorges and foothill areas, under conditions of warm and humid climate, with summer precipitations (Morlans, 1995).

In Argentina, the Yungas cover an estimate surface of 5.2 million hectares, along 600 km in a North-South direction through the Provinces of Salta, Jujuy, Tucumán and Catamarca, and even though they do not exceed the 100 km wide, they extend in a wide range of elevations which vary between 400 m and 3,000 m above sea level (Brown *et al*, 2006).

The Yungas are divided into four sub-regions: transitional jungle sub-ecoregion, montane jungle sub-ecoregion, montane forests sub-ecoregion and montane or fog grasslands sub-ecoregion. The montane forests consist of wooded areas which develop between 1,400 and 2,500 m over sea level and are very important since they regulate watersheds (Fra *et al*, 2007), representing the understory layer of the fog forests.

In the Province of Catamarca, the Yungas are found in the Northeastern region of the County of Andalgalá, as well as in the Northern and Western regions of the Counties of Paclín and Ambato (Morlans, 1995), where there are four formations of montane forests with characteristic species such as *Podocarpus parlatorei* (pine forests from the Ambato Mountains, the Ancasti Mountains, the Graciana Mountains and the Potrerillos Mountains), the only conifer of Argentina's Northwestern region (Fra *et al*, 2007). Nevertheless, the Yungas found in Catamarca are the southernmost manifestation of this phytogeographic formation, so it is considered as impoverished with a loss of

vegetation continuity -especially in the higher altitudinal levels-, alternating profusely with the mountain Chaco and, to a lesser extent, with prepuna or puna areas (Cabrera, 1976).



**Figure 1:** Yungas area **a)** in South America and **b)** in Argentina (Source: Fundación Proyungas)

*Podocarpus parlatoarei* Pilg. (Figure 2) is a dioecious tree of variable height -between 6 and 20 meters high-, which usually forms quite monospecific forests in the higher layers or grows in mixed forests in codominance with species such as walnut trees (*Juglans australis*), cedars (*Cedrella lilloi*) or several species of the Myrtle family at a lower height (Blendinger, 2006).

It is considered that *Podocarpus parlatoarei* Pilg. can have a key function in the dynamics of these ecosystems, since it is a pioneer species of open areas which inhabits abandoned crops and disturbed areas (Blendinger, 2006). Its black drupe and fleshy fruit is eaten and spread by several bird species.

It has been noticed that the water collection function, characteristic from all cloud forests, is particularly important in the Argentinean Yungas, given that the regional productive system of the lowlands mostly depends on the irrigation that the Yungas provide (Brown *et al.*, 2006), since 90% of the precipitations are produced in a period of no more than six months, from November to April (Huzinger, 1997). Thus, the decrease of areas covered by Yungas could have a critical impact on the biodiversity of these regions (Brown *et al.*, 2006).

It is worth mentioning that *Podocarpus parlatoarei*, like other endemic species from the Yungas, is still protected by CITES (Convention on International Trade of Endangered Species of Wild Flora and Fauna) against the excessive exploitation due to international trade. As it is known, CITES is an international agreement executed by the governments whose purpose is looking after that the international trade of wild flora and fauna species does not constitute a threat to their survival. However, different studies have evidenced that the surfaces covered by Yungas in Argentina have increased in recent years, as a response to an increase of precipitations and changes implemented in the development of resources (Grau *et al.*, 2007).

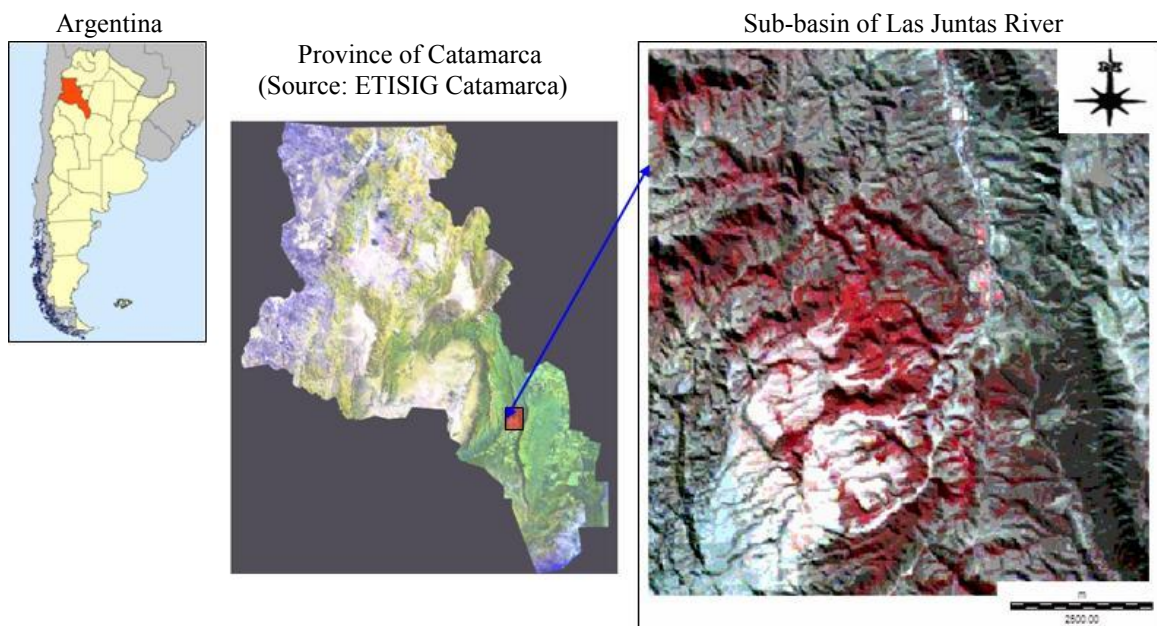
The dynamics of the Yungas in Catamarca has not been studied in detail yet. Consequently, a pilot area has been selected (Figure 3) corresponding to the sub-basin of the Las Juntas River (County of Ambato), located between a latitude of 28° 03' and 28° 14' South and a longitude of 65° 48' and 65° 58' West, whose elevations vary between 1,650 and 2,000 meters over sea level, for the purposes of detecting possible modifications experienced by the montane forest of *Podocarpus parlatoarei* and identifying if it occurs a similar process which has been noticed in other Yungas of the Argentinean Northwestern region.





**Figure 2:** Left: *Podocarpus parlatorei* Pilg in Ambato. Right: Yungas in the Basin of Las Juntas River, Catamarca

This work seeks to provide a contribution to the knowledge of the Yungas' dynamics in the Province of Catamarca and will allow inferring if the changes herein detected are associated with the regional process of expansion of forests which has been mentioned by diverse authors, and researching on their probable causes.



**Figure 3:** Area under study corresponding to Yungas in the sub-basin of Las Juntas River, Catamarca (Argentina) – 2-3-4 composition of Landsat TM, 2010

## AGRO-GEOGRAPHIC CHARACTERISTICS OF THE AREA UNDER STUDY

The Province of Catamarca, located in the Northwestern region of the Argentine Republic, has a surface of 102,602 km<sup>2</sup> and extends from its north end point -Azufre Volcano in the border with Chile- from 25° 09' South latitude to the South end point -Landmark X, three-way convergence with the Provinces of Córdoba and La Rioja- corresponding to 30° 08' South latitude. In East-West direction, its surface extends from the end point located at the East of the Salinas de San Bernardo (salt pans) and the point located at the North of Cerro Vidal Gormaz (mountain) -in the border with Chile-, that is, between 64° 47' and 69° 06' West longitude (I.G.M. [Military Geographic Institute], 1987).

The political division of the province has 16 counties with a total population of 367,820 inhabitants (INDEC [National Statistics Board]: National Census of Population, Homes and Housing, 2010), forming one of the lowest densities of Argentina: 3.6 inhabitants/km<sup>2</sup>.

The County of Ambato, located at the central region of the provincial territory, with a surface of 1,797 km<sup>2</sup> and 4,468 inhabitants (I.N.D.E.C., 2010), has a demographic density even lower than the provincial mean value: 2.5 inhabitants/km<sup>2</sup>.

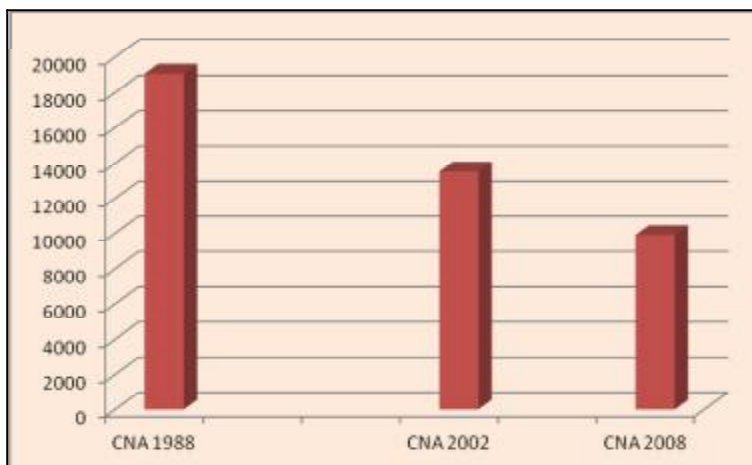
The volume of the county's population shows through the different national censuses that it is far from accompanying the provincial demographic growth. As it can be seen in Table 1, the inter-census variations are mainly negative, i.e., -1.4% for the period 2001-2010.

The population which is closest to the area under study is in the village of Las Juntas, with 322 inhabitants (INDEC, 2010). Moreover, Ambato is the provincial county with the biggest number of uninhabited homes: 60% (INDEC, 2010), since the villages such as Las Juntas modified their cattle-farming activity and replaced it by a strong tourism interest, thus, they are characterized by the use of their constructions for holidays purposes.

**Table 1:** Population from Ambato and Provincial Population according to National Censuses

Year	Total Inhabitants Catamarca	Total Inhabitants Ambato
1895	90,161	3,114
1914	100,769	2,676
1947	147,213	3,665
1960	168,231	3,538
1970	172,323	3,552
1980	207,717	3,500
1991	264,234	3,582
2001	334,568	4,525
2010	367,820	4,468

The Agricultural National Census 1988 stated the existence of 19,067 heads of cattle in said year for the County of Ambato. The Agricultural National Census 2002, after fourteen years, detailed 13,523 heads of cattle, showing a strong decrease in the county's cattle density. The National Agricultural Census 2008, however, confirmed this tendency of loss of livestock since it registered 9,907 heads of cattle.



**Figure 4:** County of Ambato: Heads of cattle in the period 1988-2008



The National Agricultural Census 2008 evidences that other animal husbandry operations such as sheep (456 heads), goats (646 heads) and pigs (60 heads) have little effect on the county's economy.

The area under study belongs to the sub-basin of the Las Juntas River which has its source in the foothills of the Ambato Mountains. From a structural point of view, the territory belongs to the Pampean craton or *Sierras Pampeanas* (Pampas Mountains) which has remained as a positive area since the Pre-Cambrian.

Beyond the specific aspects of its evolution, it has been pointed out that the diastrophism which originated the Andes Mountain Range in the Tertiary Period cracked the Western section of the craton with tectonic movements of elevation of large blocks throughout the faults lines -mostly, in a North-South direction- and the sinking of other blocks which would later form the valleys. In consequence, the Pampas Mountains that extend in the central and eastern region of the Province of Catamarca are not fold mountains, but a set of rising blocks with different heights by means of faults.

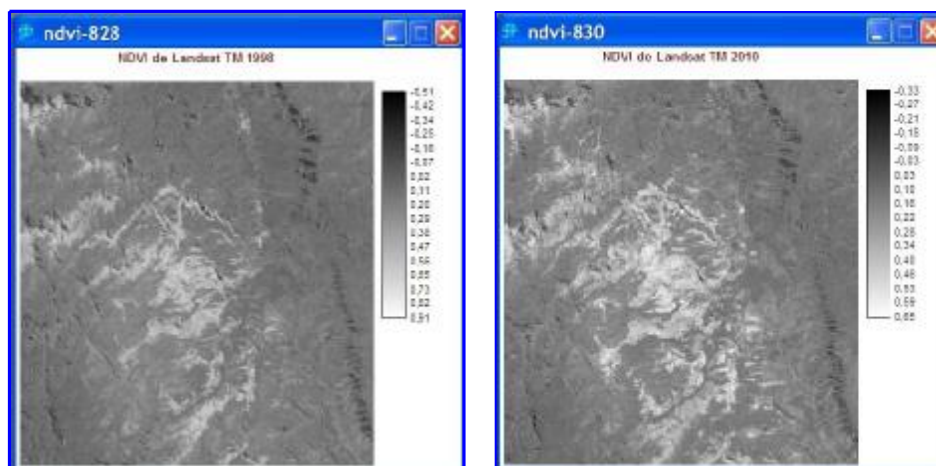
The area under study has particular microclimate conditions, with average precipitations which can exceed the 900 mm a year, which are produced between November and April. However, it is necessary to mention that the pluviometric records from Las Juntas Station, provided by the Environment and Water Secretariat from the Province of Catamarca, constitute an incomplete series lacking the annual precipitation data since the year 1988, which makes it difficult to establish relations between availability of water resources and forest coverage. However, some dendrochronological studies of the Argentinean Northwestern region (Ferrero et al, 2007) suggest that from the last two centuries, the recent decades (from 1970 on) form the most humid period of the region.

## MATERIALS AND METHODS

From Landsat TM images provided by CONAE (Argentine National Commission of Space Activities) in function of the cooperation agreement executed with the National University of Catamarca, it has been possible to determine the surface covered by Yungas corresponding to the area under study, in the years 1998 and 2010, in order to compare the spatial distribution and analyze the changes produced in a period of twelve years.

The images used correspond to bands 1, 2, 3, 4, 5 and 7 of Landsat TM (path 231, row 70) dated 08/27/98 and 08/28/2010, taken during the dry season, for a better differentiation of the spectral assessment of the particular perennial species from the Yungas, considering the absence of herbaceous plants.

The study of vegetal covers included the determination of the reflectivity contrasts, given that the healthy vegetation presents low reflectivity in the red spectrum portion (band 3 of Landsat TM) and high reflectivity in the near infrared (band 4 of Landsat TM).



**Figure 5:** Simplified NDVI for assessing vegetal covers – Left: Year 1998 – Right: Year 2010

Even though the Normalized Difference Vegetation Index (NDVI) is calculated based on the red reflectivity and near infrared reflectivity and not on the basis of digital levels for the purposes of a relative assessment of vegetal covers, it is widely acceptable using the bands corresponding to said spectrum portions.

The application of NDVI through the Idrisi software (Clark University, Massachusetts, USA), with the digital levels of bands 4 and 3, has allowed observing that the highest vegetal strength -high digital levels- corresponds to the year 2010, as it can be seen in Figure 5.

The preprocessing and standardization of the satellite data have included atmospheric corrections and spectral similarity analysis. In other respects, geometric adjustments have been made based on the mosaic of Landsat

images from the province, at a 1:500000 scale from ETISIG Catamarca (Interinstitutional Work Team in Geographical Information Systems).

The digital treatment of the images has included the calculation of statistics, analysis of correlation between bands and expansion of contrast (linear with saturation based on the distribution function) to identify the Yungas' cover.

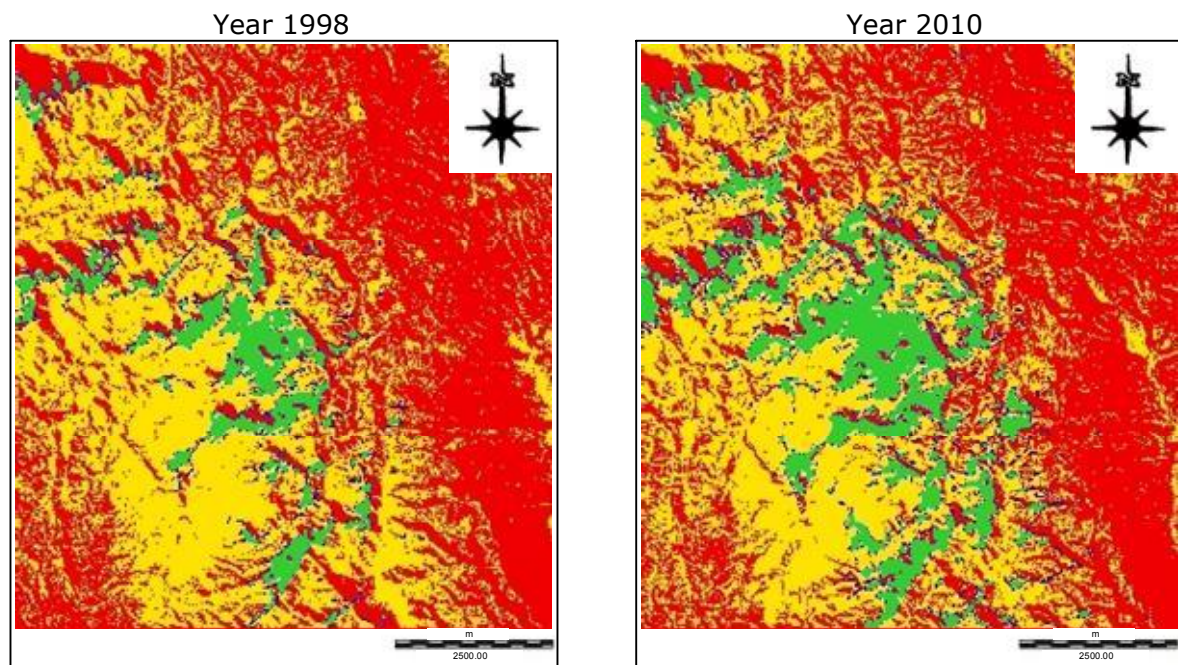
The spectral class corresponding to the montane forest has been separated with assisted classification, by means of the application of criteria of maximum probability on 6 bands (1, 2, 3, 4, 5 and 7). With in situ inspections, three training sites have been selected for the montane forest and other four for the rest of the covers. Such sites have been assessed through signature graphs and statistical divergence to ensure the severability of the forest category. In order to have an approximation to the degree of reliability of the classification, the confusion matrix has been calculated on the basis of control points conveniently selected in terms of accessibility.

## RESULTS

The results obtained by applying remote sensing techniques can be seen in Figure 6. In both images, the green color represents the montane forest, on basis of a mean classification error of  $\pm 2\%$  for a 95% confidence interval.

From the calculation of areas carried out with the software, it can be understood that for the area under study, from 511 hectares occupied by the Yungas' montane forest in the year 1998, there has been an increase to 1,014 hectares in the year 2010, confirming an expansion process similar to other processes detected in other Yungas of Argentina's Northwestern region. It is possible that said process responds to an increase of precipitations and changes implemented by the ways of developing the resources.

The decrease of stockbreeding, the rural-urban migration, the socioeconomic changes and more humid climate cycles are aspects which can be connected to the detected phenomenon.



**Figure 6:** Spatial distribution of Yungas in the Sub-basin of the Las Juntas River, Catamarca

## CONCLUSIONS

The increase of the area covered by the species *Podocarpus parlatorei* on the sub-basin of the Las Juntas River, County of Ambato (Catamarca, Argentina) has been confirmed through the application of remote sensing techniques.

From the calculation of the areas made with the software, it can be inferred for the site under study that the Yungas montane forest covered -with some discontinuities- 500 hectares in the year 1998. Said surface has increased in a 100% in the year 2010.

It is possible that the process of forest expansion detected is related to the increase of precipitations which different authors notice in the region, and also to the demographic decrease, the gradual discontinuance of cattle development and to the changes made to the forms of developing resources in general in the area under study.

However, the strong variability observed indicates the need of studying this in depth so as to understand in which way the demographical, socioeconomic and climate phenomena are associated with the recovery of *Podocarpus parlatorei* forests and to have a better understanding of the reproduction mechanisms of these species.

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