TERRAIN ANALYSIS

One main objective was to develop several Hydrological Models to serve as a base for other modeling. All of these models require information about the watershed. Hence, all the available information that could be useful to the definition of the watershed of the Ibera system was compiled.

Topographic Map

One main source of information were cartographic maps of the "*Esteros del Iberá*" developed by the Military Geographic Institute (*IGM, Instituto Geográfico Militar*). Nineteen maps in the scale 1:100000 were required to cover the study area. The main information retrieved from the maps were the **Level Curves (LC)**. We decided to use the LC in order to define the limits of the watershed by using a Geographic Information System (GIS). Hence, our first step was to digitalize the LC and use the GIS functions to define the watershed.

During this process it was discovered that the LC in the maps were insufficient. In some places information, such as bathymetric data, (*Fig. 1*), was missing, and in others the LC presented some discontinuities (*Fig. 2*). As a way to solve the lack of information, we tried to complete the maps with data retrieved from other documents. We recovered data from phitogeographic maps, from soil maps developed by INTA (Instituto Nacional de Tecnología Agropecuaria), from geomorphological studies and flux analysis maps (Estudio del Macrosistema Iberá–ICA-1981), These were added to remote sensing data and the information provided by the bathymetric studies made by Laboratorio di Idrobiologia di Roma (*Fig. 3*). The results allowed us to infer the Topography in the areas where the topographic maps are incomplete. All the information was drawn by hand into a unique topographic map (*Fig. 4*). It is necessary to remark that this output could be further improved with more detailed studies in situ.

The complete topographic map was scanned and afterwards all the LC were digitalized. The digitalization process involves redrawing all the LC using

Figure 1. Sample of topographic map without bathymetric information

Figure 2. Sample of discontinuities in topographic maps

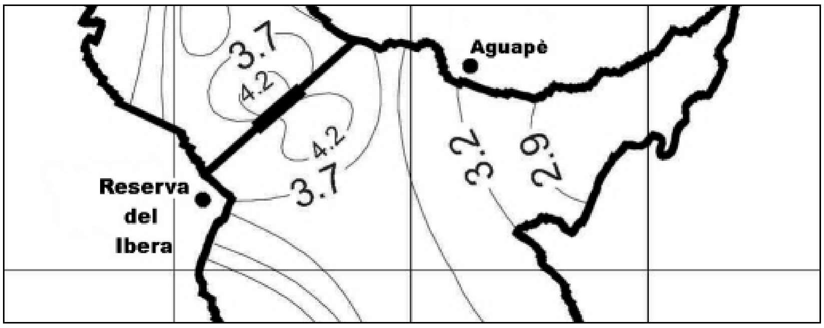

Figure 3. Sample of bathymetry performed by LabRoma.

an appropriate software tool. Each curve was assigned an identity number (related we the altitude a.s.l.), and all the LC were stored in a vector file format (DXF). The time of processing all the curves was considerable due to there are almost 13000 segments (*Fig 5 & 6*).

In order to incorporate the LC into the GIS it was necessary to georeference the file produced. As a first step, colleagues allowed us access to software that performed this process. Once we tested the performance, we begun to discuss which software to acquire. We exchanged experiences with UNISI, CONAE (Comisión Nacional de Actividades Espaciales), and colleagues from Geographic Research Centre (CIG, Centro de Investigaciones Geograficas) at our University. Since UNISI and CONAE were using ERDAS software packages, CIG colleagues strongly recommended it, and because of the need for compatibility between partners, we decided acquire ERDAS 8.4 which, in Argentina, is packaged together with ARC-VIEW 3.1.

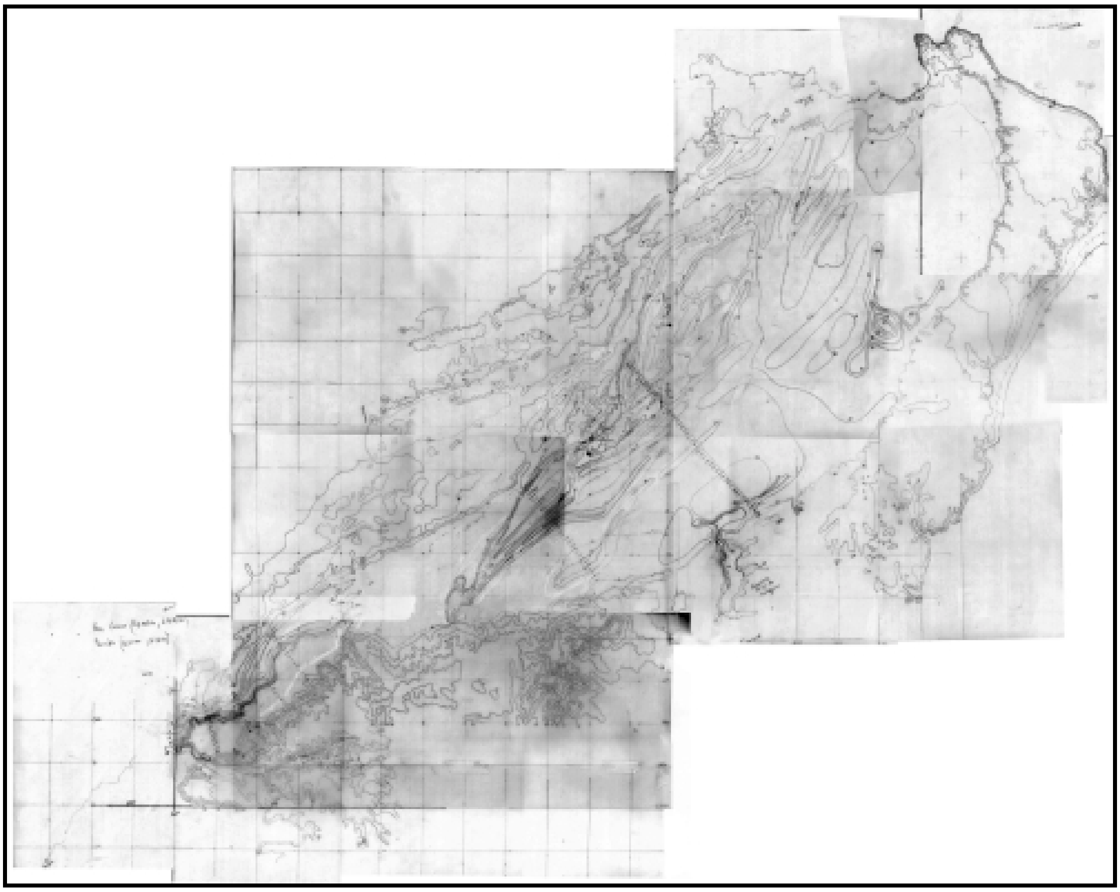

Figure 4. Hand-drawn topographic map with compiled information

At this point, the DXF file produced was imported to the GIS and georeferenced. The process of assigning coordinates in any system to a vector or image file, is known as **registration**. In Argentina all geographical information is expressed in the Gauss-Krüger Coordinate System. Hence, it was decided to use this same coordinate system. Vector and Image registration requires that a set of

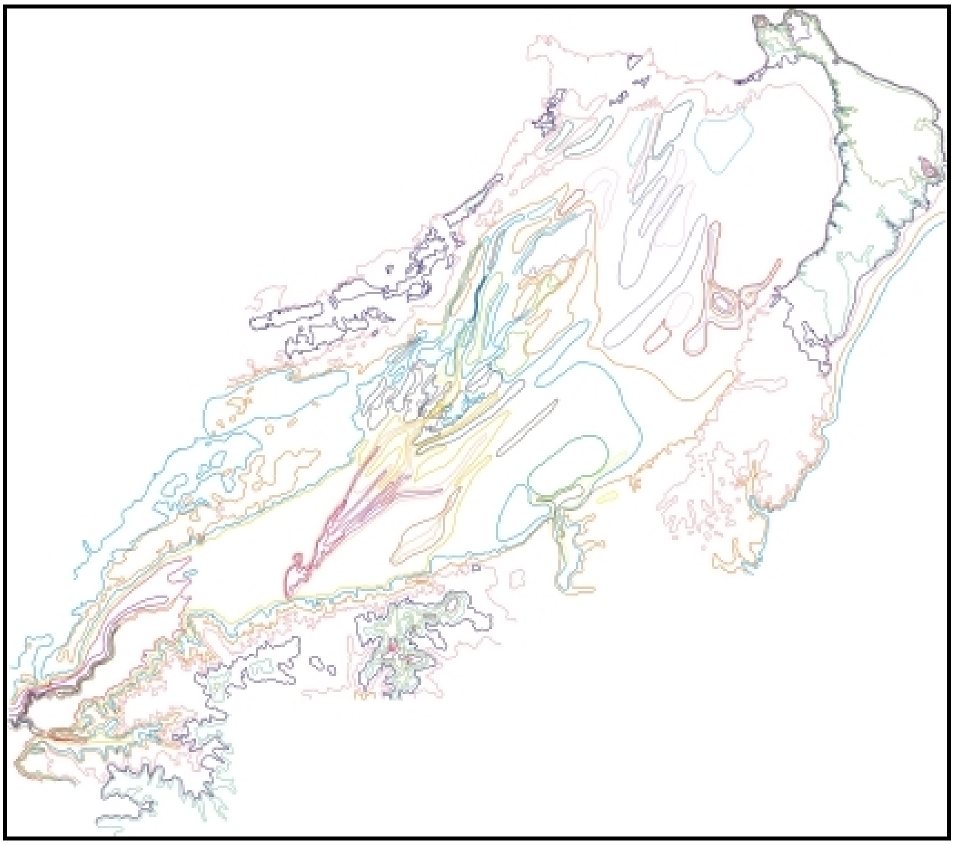

Figure 5. Digitalized topographic map.

Figure 6. Detail of digitalized level curves.

Ground Control Points (GCP) are marked and map coordinates entered manually for each point. Once enough points have been picked, the definitionof a warp polynomial requires the execution of the **Warping** and **Resampling** processes. The warping process selected is known as RST (Rotation, Scaling and Translation). This is the simplest method and it is particularly efficient with flat coordinates. Due to the fact that the vector file is a flat map, we used a linear warp polynomial. The resampling process selected is know as Cubic Convolution. Cubic convolution to resample the vector or image file uses 16 pixels to approximate the sine function with cubic polynomials. Note that cubic convolution resampling is significantly slower than other methods. After all these processes a georeferenced vector file containing all the Level Curves was obtained.

Digital Elevation Model

A Digital Elevation Model (DEM) is an image file that records the corresponding altitude in each pixel of the map. To build a DEM from a set of LC it is necessary to perform a bidimensional interpolation.

The first step is transforming the previous vector file into an image file, a process known as **rasterizing**. It was decided to start with an image (or map sheet) with a spatial resolution of about 100 meters per cell size and rasterize the LC into it. It is particularly important that contours (vector lines) intersect the edge of the map sheet exactly, because the algorithm ignores all the lines that fall outside the image area. Any pixel not containing a curve segment was assigned a zero value. In addition, it was necessary to estimate manually the altitudes of the four corners of the study area based on the contours. After this was accomplished, the interpolation process was performed. The interpolation process requires a total of six passes over the image following different directions.

Later, the created DEM is resampled in order to obtain a DEM with a spatial resolution of 180 meters (*Fig. 7*). This is required for a later overlapping with SAC-C satellite images. After interpolation was finished, it became indispensable to run several times a mean filter operation in order to remove some of the angularities of the linear interpolation (*Fig. 8*).

With the newly created DEM we develop an **Aspect** image. In an aspect image we can see the direction in which a slope runs. This is determined as the direction facing downhill at the line of steepest descent (*Fig 9*).

Once the Aspect image was developed, the Corriente river was marked as an output point of the region (at coordinates X=6350000 and Y=6794840 in the Gauss-Krüger reference system, or –58° 32’ 19.9742” Longitude and –28° 58’ 27.6618” Latitude). At this point it was possible to run the watershed definition process. The watershed definition process returns a binary image where 0 values are sites located out of the watershed, and 1 values are pixels contained in the watershed (*Fig. 10*). This process combs the region following the slope faces, and for this reason it is very important to run a mean filter operation previously. Otherwise the process can suffer an unwelcome interruption.

After the watershed process was finished, the GIS internal functions could create a vector file that delimits the watershed image obtained (*Fig. 11*).

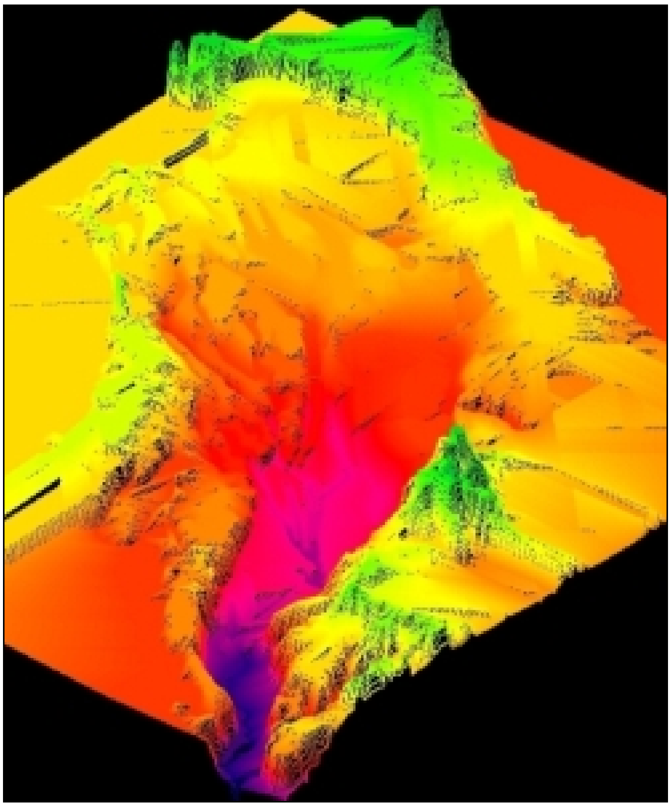

Figure 7. Initial Digital Elevation Model (DEM)

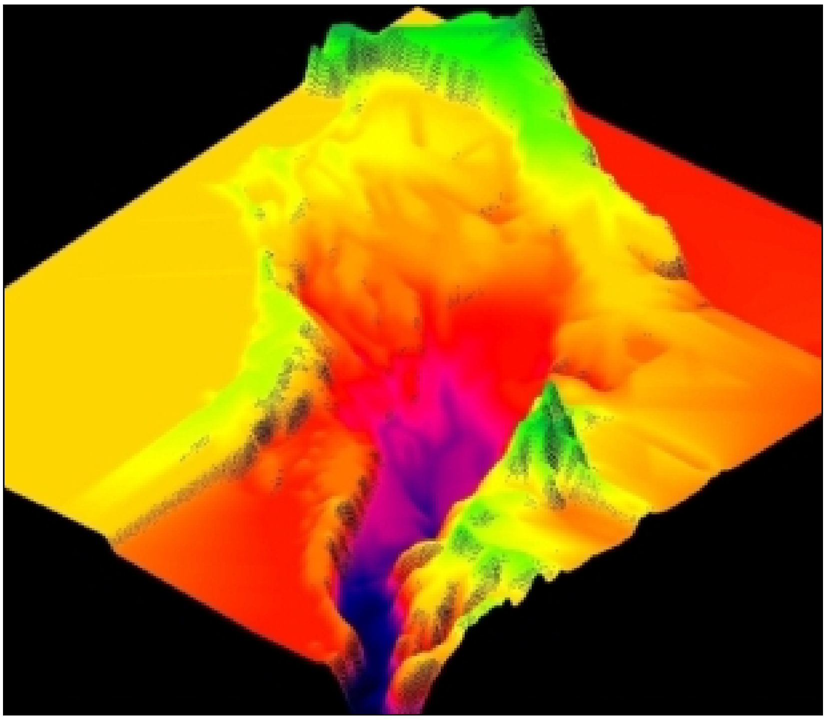

Figure 8. Smoothed Digital Elevation Model (DEM)

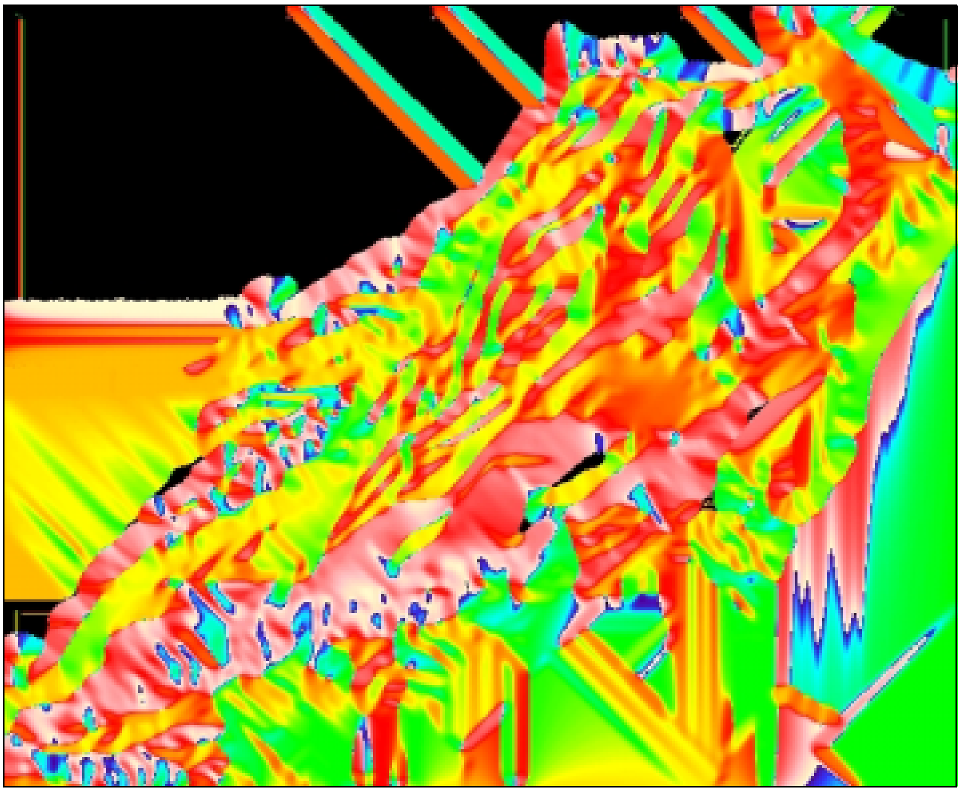

Figure 9. Aspect image (steepest descent) of the Digital Elevation Model

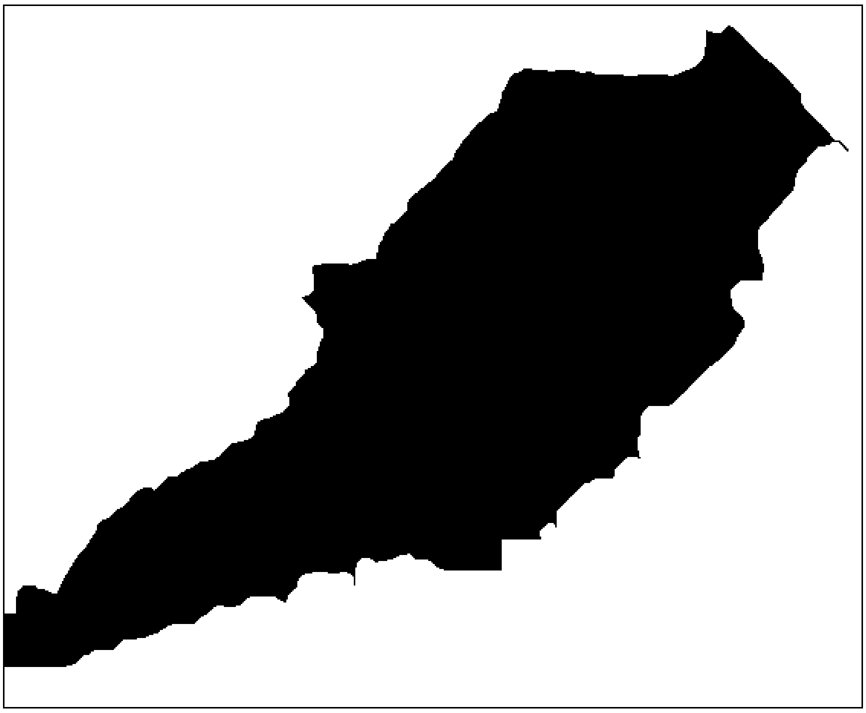

Figure 10. Definition of the watershed using the Aspect image.

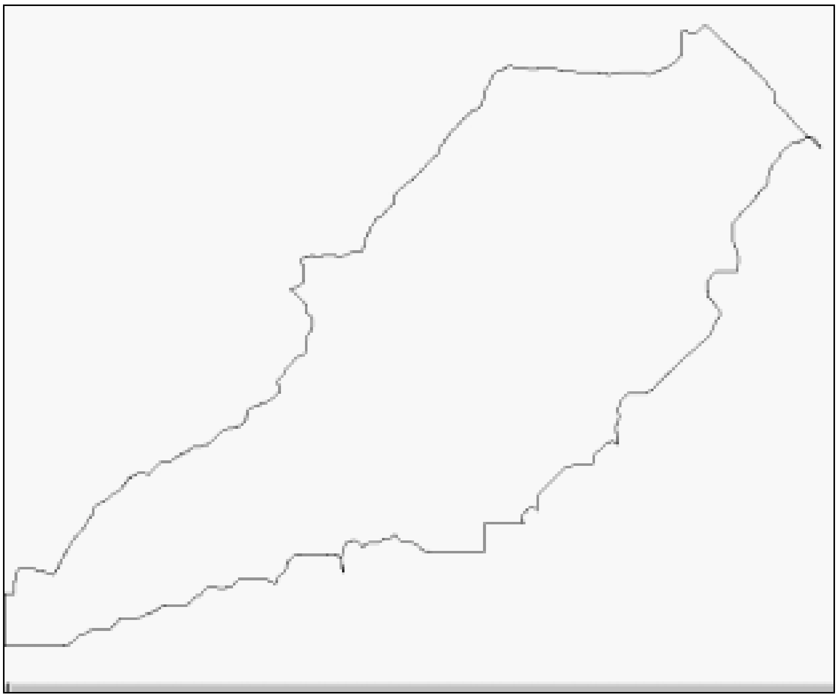

Figure 11. Vector file of watershed borders.

Satelital Images

Since this Project was approved to be part of the SAC-C Mission, CONAE provided us with all necessary satelital images. Because of the SAC-C launching was delayed until November 18, 2000, we received LANDSAT 5 images instead. Some LANDSAT 5 images were preprocessed at CONAE making their resolution similar to that of SAC-C images. A "*historical*" LANDSAT 5 mosaic image composed by different images from several dates between June and July 1986 was also provided.

The registration process applied to the Level Curves vector file was also applied to all the satelital images received from CONAE. Once the file is displayed, image registration requires that a set of Ground Control Points (GCP) be marked and map coordinates be entered manually for each point. Once enough points have been picked, it is necessary to define a warp polynomial in order to execute the Warping and Resampling processes.

During the resampling process for LANDSAT 5 images, it was necessary to redefine the spatial resolution. Originally, LANDSAT 5 images have a spatial resolution of 30 meters, but in order to use them together with the SAC-C images, the spatial resolution of LANDSAT 5 was reduced to 180 meters (*Fig. 12*).

In the case of images, the GCP were selected from both satelital images and topographic maps. It was necessary to chose points, such as roads intersections, that are easily detected in the images and, moreover, which coordinates are easy to retrieve from the maps. In some cases, it became convenient to display the image using a False Color combination that enhanced the contrast of the GPC searched. Due to variations in contrast between images,

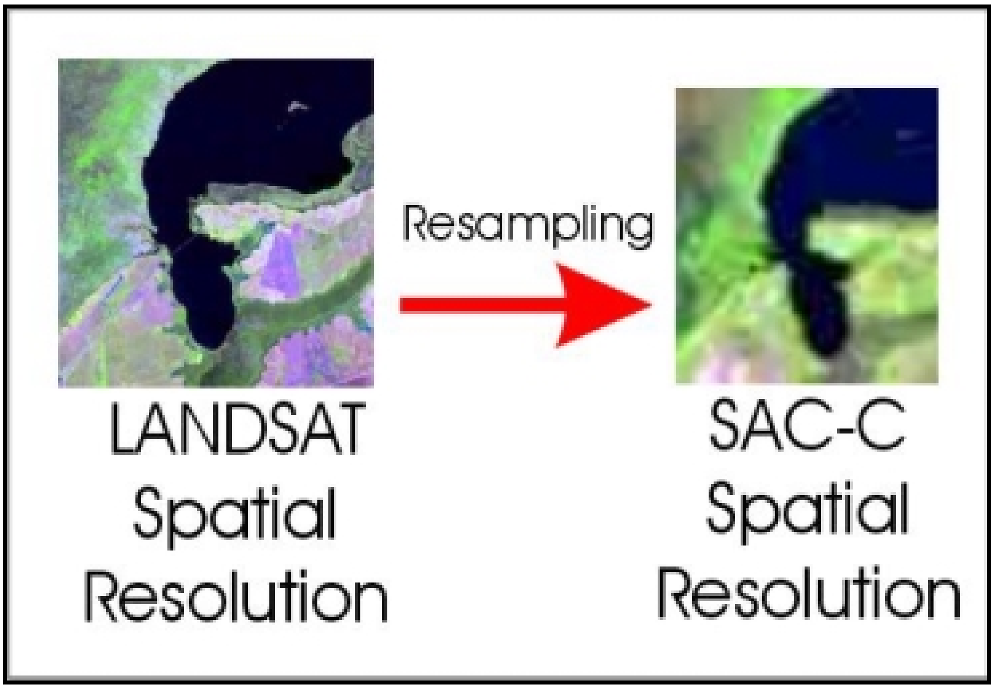

Figure 12. Comparison of resolutions between LANDSAT and SAC-C images.

different GCP were taken for different images. Both processes (the localization in the image and the localization in the map) incorporate measurement errors. In order to quantify these errors, a vector file was created containing the Iberá Lagoon for each georeferenced image. With an overlay comparison process, it was possible to assess that files differ in three pixels at most. The warping process selected was RST, and the resampling process selected was Cubic Convolution.

Georeferenced Image Files

After these processes, the georreferenced image files were obtained. Once the georreferenced images were ready, it was possible to merge the images form different Paths and Rows, creating “mosaic” images of the whole region of study.

At this point the watershed and the images had been georreferenced. Hence it was possible to use the GIS function to overlay the watershed boundaries into the satelital images (*Fig. 13 & 14*).

Classification

There are numerous methods available for enhancing spectral information content of LANDSAT data. In fact, many enhancements are specifically designed to feature vegetation, such as NDVI, DVI, Tassel Cap, etc.

The goals of the utilization of satelital images in this project were:

- To develop some kind of index to evaluate Habitat Quality that could be incorporated into the species population models.

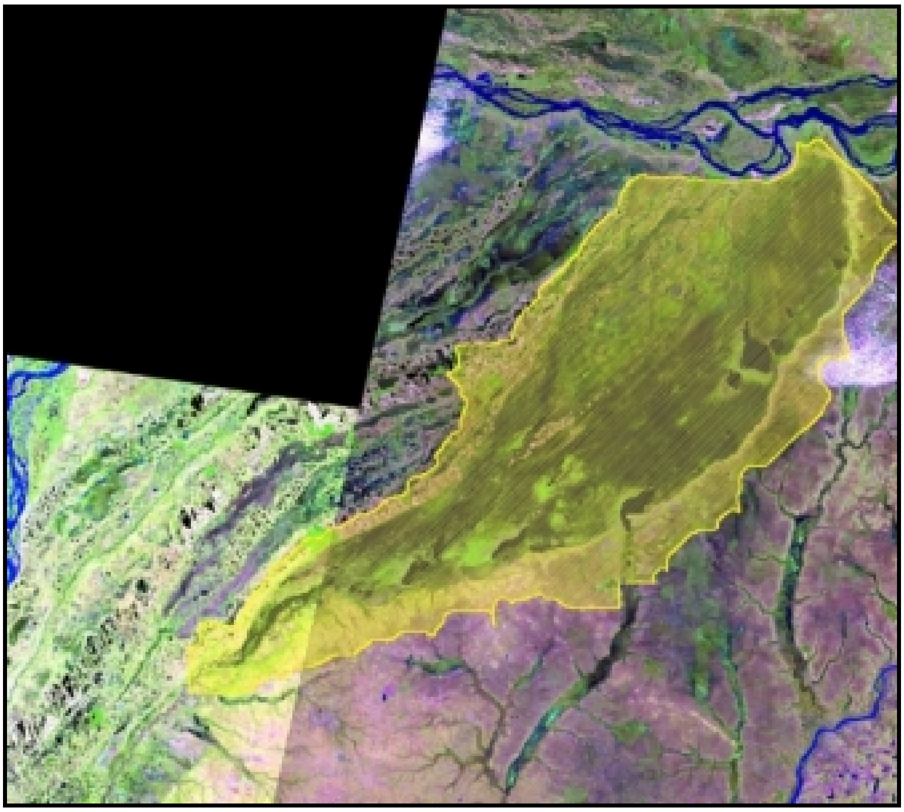

Figure 13. Watershed overlapped on a LANDSAT 5 image from 1986.

- To develop some kind of index to evaluate the vegetation roughness parameters that conditions the surface flow in the Hydrological Models.

The **Tasseled Cap (TC)** transformation was originally designed for LANDSAT TM images. The TC indices relate six TM bands (1-5 & 7) to measures of vegetation (greenness), soil (brightness) and the interrelationship of soil and canopy moisture. Each index corresponds to a linear transformation of six TM bands using a set of empirically derived coefficients. Afterwards, the information present in the 6 original bands is compressed into 3 TC transform bands.

In order to develop some kind of index for habitat quality following the philosophy of HEP (Habitat Evaluation Procedures) the variables under consideration are vegetation, water (or distance to water bodies), and some evaluation about the usefulness of the terrain (protection, etc). TC was especially interesting because it allows to extract almost all the information needed to define HEP indexes from satelital images.
The original TC transformation can only be applied to LANDSAT images. It can not to be applied to SAC-C images due to the absence of the 7th TM band. For this reason we use the **Modified Tasseled Cap (MTC)** transformation, developed by our colleagues at UNISI, that can be used with the five SAC-C bands. Hence it was possible to apply the MTC transformation to all