

**Application of GIS and Remote Sensing for artificial reforestation
monitoring in 7th Maule Region, Chile:
An example in Empedrado Comuna.**

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1. Introduction.

The main objective of land cover studies involves mapping and inventorying of cover classes and uses for a given geographical space. Land cover mapping is essentially for support territory planning, for that is necessary to know the current use of land in order to propose any improvements (Chuvieco, 1985). Land cover surveys allow us to estimate precisely the forest, crop-fields, urban areas variations, and to detect any changes for communication network planning, for example.

Remote sensing techniques provide us valuable tools for evaluate rapidly environmental phenomena. GISs are also very appropriated facilities for describing and applying spatial distributions of such phenomena. Thus a GIS could be considered essential an applied technology for solving territory problems (Bosque, 1992). Digital Elevation Models (DEMs) enables to develop this type of studies, for that gives maps of slope and aspect with simple operations and processes.

2. Objectives.

This study involves to apply remote sensing techniques, raster GIS and DEM in order to evaluate land cover dynamics between two different dates (1961 and 1989). We have proposed two steps:

- a) To assess exactly the change in agricultural surfaces.
- b) To determine which type of cover were involved in the transformation.
- c) To generate a DEM for obtaining information about altitudes, aspect and slope.
- d) To correlate land cover maps of 1961 and 1989 with information derived from DEM.

3. The study area.

The Empedrado Comuna is located in the south-west extreme of Talca Province, in the 7th Maule Region, Central Chile, 250 Km south from Santiago. Its extent is 563.5 Km², situated between 35°30' - 35°43' south latitude and 72°01' - 72° 27' west longitude. It has a population of 4,549 inhabitants (density of 8 inhabitants/km²).

4. Methodology.

The technical and methodological process followed in this dynamic cartography of land cover were:

We started with an approach to the knowledge sources upon which different techniques were applied in order to observe and express data, facts and phenomena. And finally we have employed appropriate work methodologies for these sources, in order to interpret and to obtain the maximum profit and best results from that information.

We have acquired a photographic mosaic from 1961 (Air-photogrammetric Project OEA/CHILE/BID, Ciren-Corfo, 1979) and Landsat4-TM data (printed format) from 1989, corresponding to 7th Maule Region.

These were our main analogical sources for the study. These two documents would be supported by other previous ancillary data: topographic map at 1:50,000 scale from Military Geographical Institute (Sheet from Empedrado), aerial black and white metrical photographs at 1:20,000 scale and color non-metrical at 1:10,000 scale, corresponding to the study area. Finally, a literature revision were made, as well as our own knowledge or the site.

The following steps were performed in order to obtain the land cover maps: visual interpretation of the images, photogrammetric information transference, data preparing, digitizing, raster editing and interpolation.

Regarding to DEM, contour lines, some elevation points and critical features of relief were digitized by using ARC/INFO vector GIS (ESRI, 1990). Equidistance between each contour lines were 50 meters. This layer was geocoded using TRANSFORM algorithm, resulting a input RMS of 0.0012. The digital analysis were to be performed in a raster GIS, and thus a format change were done, employing LINEGRID ARC/INFO command, which converts vector data to raster one. The final layer had a pixel size of 50 x 50 meters, and 412 rows by 430 columns. Then digital model was generated using a linear interpolation algorithm (INTERCON) within IDRISI raster GIS (Eastman, 1992). In order to verify the model, 119 random points were sampled and those were analyzed by Pearson linear correlation coefficient, which is expressed as:

$$r = \frac{\sum_i ((X_i - \bar{X}) \cdot (Y_i - \bar{Y}))}{\sqrt{\sum_i (X_i - \bar{X})^2} \cdot \sqrt{\sum_i (Y_i - \bar{Y})^2}} \quad (1)$$

where numerator is the covariance of both variables, while the denominator represents standard deviations of each variables. The value of r was 0.99. Therefore, altitude, slope and aspect information were derived from this DEM.

5. Results and conclusions.

Regarding to technical and methodological topics aspects, we could ensure that these new investigation supporting tools, were validated as well as other traditional spatial data collecting and processing methods; those in fact, contributes to save resources and to improve result quality). The DEMs have been consolidated as useful documents for topographic analysis, due to its digital format which makes easy to integrate into a GIS system.

A preliminary analysis of the results allows us to appreciate in the following table changing categories of the study period. It would be detached that this same legend had been in the Air-photogrammetric Project OEA/CHILE/BID.

As Table 1 shows, it is significative that domestic orchards had disappeared (49.7 has), natural forest (1,663.5 has), natural prairie (851.2 has), natural prairie and renewal (2,576.5 has) and natural prairie and shrubland (1,963.5 has); all of them occupied a total sum of 7,079.5 has, that corresponds to 30.05% of the whole study area.

Plantation forest and clear-cuts and renewal categories have experienced the major increase. The first one had increased from 3,322.7 has in 1961, to 12,129.0 has in 1989, which implies that the absolute increment was 365.5%; the second one had 4,393.7 has in 1961 and reached to 10,597.5 has in 1989, with a relative growth of 241.2%.

Table 1. Land cover maps comparing

Categories	Surface (in hectares)	
	1961	1989
1. Urban area	24.5	54.3
2. Domestic orchards	49.7	-
3. Cereal-pasture rotation	5,035.7	155.5
4. Extensive cultures and natural pasture	3,672.7	617.8
5. Clear-cuts and renewals	4,393.7	10,597.5
6. Natural forests	1,663.5	-
7. Plantation forests	3,322.7	12,129.0
8. Natural prairie	851.2	-
9. Natural prairie, clear-cuts and renewal	2,576.5	-
10. Natural prairie and shrub	1,963.5	-
TOTAL	23,554	23,554

By analyzing the evolution of land cover an important change had been detected, which reaches 19,544.2 has, that is 88.9 % of study area, staying unchanged 4,009.8 has, which represents 11.1% of whole extent.

On the other hand, we could confirm the incidence of Decree Law 701 referred to forest plantation, related to bonification settled in such Decree, in terrains that had mainly forest aptitudes.

The Empedrado Comuna is situated aside of Constitución Comuna, where "Celulosa Celco" company is situated. This is one the most important private company, and this fact had facilitated to buy fields in such rural comunas for forest plantations.

6. References.

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ESTABILIDAD - DINAMICA DE LA OCUPACION DEL SUELO, 1961 - 1989

