AGRO-GEOGRAPHICAL ZONING WITH LANDSAT IMAGES IN CATAMARCA (ARGENTINA) AS A BASE FOR PLANNING DEVELOPMENT

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Key words: homogeneous rural zones, decision-making processes, digital satellite images, zone boundaries, spectral information.

ABSTRACT

Cadastral legislation in some Argentinean Provinces establishes –in explicit or implicit way– the necessity to determine homogeneous rural zones as a previous stage to obtain cadastral valuation at a zonal and parceling level.

The economical cadastral scope consisted historically in the appraisal of values of real properties in order to fix property tax. The cadastre's present conception, as an interdisciplinary and multipurpose land information system goes beyond the mere tributary objective, assuming a decisive role in territorial objects knowledge and their distribution, as a base for development planning. In this way, the agro-geographical zonings that are resolved in Argentina from provincial cadastres provide the information required in decision-making processes and constitute an important instrument that allows the designing of policies related to territory and natural resources.

In practice, landscape is not strictly homogeneous. Therefore, the determination of boundaries of agro-geographical zones involves conceptual generalization processes through complex mechanisms of spatial differentiation.

The main difficulty in the application of geographical methods to divide a territory into regions or zones, consisted in the necessity of detailed observations of large areas. The development of indirect observation instruments, specially the digital satellite images and the image treatment softwares, allow us today to consider the statistical nature of the zone boundaries in relation to the spatial variation of land characteristics. This is a very important aspect, particularly when zones can not be associated to abrupt changes in the land surface.

The application of zoning geographical methods both with traditional territorial analysis instruments and Landsat TM images over an experimental area in the Province of Catamarca, permits the confirmation of the comparative advantages provided by the classification of the spectral information supplied by satellite images for the delimitation of homogeneous zones of the land surface, since the zone boundaries are better defined. Besides, the geo-referenced information will facilitate the feeding of land information

systems when the Argentinean cadastres evolve towards interdisciplinary and multipurpose systems.

1. INTRODUCTION

Systematized information provided by cadastres about land wealth of their administrative jurisdiction includes both qualitative and quantitative aspects that work as a basis for decision-making processes, particularly in what refers to public management for planning development and taxing matters.

Approaching cadastres in an economical way is very important, even considering that this is only one facet of its multipurpose and interdisciplinary present conception. In Argentina, cadastral valuations follow the procedures usually contemplated by the legislation of the different provinces in agreement with the parceling categories established according to the provincial agro-economical reality.

In the province of Catamarca, due to Cadastral Provincial Act 3585/80 [*Ley Provincial de Catastro 3585/80*], rural valuation implies the territorial division into geo-economical zones and dominant agricultural exploitation sub-zones in order to appraise basic values to land without improvements.

Since landscape perception is a continuum, the process of zonal delimitation may be approached from diverse spatial differentiation viewpoints. Therefore, the earth's surface division into regions or zones constitutes an essential agreement of the understanding of geographical space according to certain objectives.

The present research, developed in the National University of Catamarca (Argentina), considers some aspects of the Doctoral Thesis "Satellite Images Application in Massive Rural Valuation" (Argerich, 2000), directed by Professor Emeritus Víctor H. Haar.

The zoning developed over an experimental area in the province of Catamarca shows the different results that can be obtained through the application of different methods and the comparative advantages that satellite images provide in digital format for the delimitation of homogeneous rural zones, not only for taxing purposes, but particularly as a basis for any policy for development.

2. ZONING METHODS

The term "zone" implies a segmentation of more complex spatial realities. It has a high degree of similarity with the term "region", which stands for integrities of different sorts, such as geographical, administrative, economical, political, or of homogeneity of resources, among others.

The economical space has been defined as the application of the mathematical space over a geographical space in three different ways. From the economical point of view, the region represents a continuous space in which each part or zone that composes it has similar

characteristics which make it homogeneous. But the region can also be considered from its coherence degree as a heterogeneous space in which the different parts complement each other and establish exchanges of goods and services, constituting thus the polarized space. The third perspective defines the region as a space-plan, that is, the space established for a pre-determined goal, depending on a population organization plan or program, intending from the prospective to modify found development imbalances.

Accordingly, Roccatagliata (1986) has pointed out that the planning region is an operational concept that follows territorial development policies. Because of this, its delimitation is established in agreement with the spatial extension assigned to the actions to be taken in order to overcome particular problems, and its existence depends on the force of the policy that implemented it. Roccatagliata emphasizes that geography, as well as other sciences, cannot ignore the identification and delimitation of planning regions, since these need a geographical basis.

It is precisely in the field of geography where the terms “region” and “zone” have been deeply under consideration, outlining the need to restrict the conception of space, land surface or geographical environment proposed by the different sciences to the “concrete, finite, continuous, not homogeneous, called ‘lively’ space, where human life develops and in which each place has its value” (Rey Balmaceda, 1972).

The differentiation of homogeneous or uniform spaces is an abstraction supported from geography because it implies the isolation of one element or attribute as if the others did not exist. Thus, the distribution of a physical, biological, or human element over the land surface answers only to a part of reality and, as such, results in an abstraction. The homogeneous region determined in relation to that unique element is called generic or systematic region.

Geographical delimitation done according to the conformity or correlation of the different elements that integrate the landscape constitutes, on the contrary, the conformed space.

On the land surface or geographical environment it is possible to differentiate areas of conformity among a variety of elements (e.g., climate, soil and flora) called geographical regions. These are characterized by its relative permanence, even when they correspond to the present time. Its determination is possible through the differentiation of contents and analysis of the spatial relations on the land surface, which constitute a product of the scientific synthesis.

Geographical regions can be formal or functional, according to whether they are linked to with the existing conformity in the landscape (appearance or physiognomy), or they are considered as nodal centers or cores (function of each element inside the group).

In order to classify reality and to differentiate spaces according to their characteristic elements -delimitation of formal regions-, geography has proposed a procedure grouping in two methods: by means of coincidence of generic regions and by site association.

In the first method, each region is characterized as intersectional surfaces of generic regions, which denotes spatial coincidences of the distribution of each element or attribute independently considered through the synthesis of its scientific fragmentation. Transitional zones correspond to land surfaces where no coincidences of the different boundaries of each generic region that has been considered are found.

It has been pointed out as a major inconvenience the difficulty of establishing the number of elements to be considered, because when the analysis parameters increase, the conformity land surfaces inevitably decrease; that is, the more accuracy, the more inconveniences in the synthesis operation.

The method of site association, instead, answers to the premise that every site is different from the neighboring one because that difference is what has established the border among them, considering site as any homogeneous parcel on the land surface.

According to the homogeneity criterion, the delimitation of land surface will be more or less extended, since the homogeneous character does not mean equality in the strict sense. Due to that, it is maintained that the site association is performed by means of the application of generalization criteria to the land surface, on the basis that there must be more disparities than similarities. Criticism has been centered on the conceptual difficulty presented by the terms “site” and “association”, and on the need stated by geography about carefully observing and understanding the complete territory to be divided into regions. However, the evolution of information systems and remote sensing instruments nowadays facilitate the application of the method of association of sites for the delimitation of homogeneous zones on the land surface. Here their statistics are complex functions of the spatial variation of their attributes, the chosen scale and the representation method.

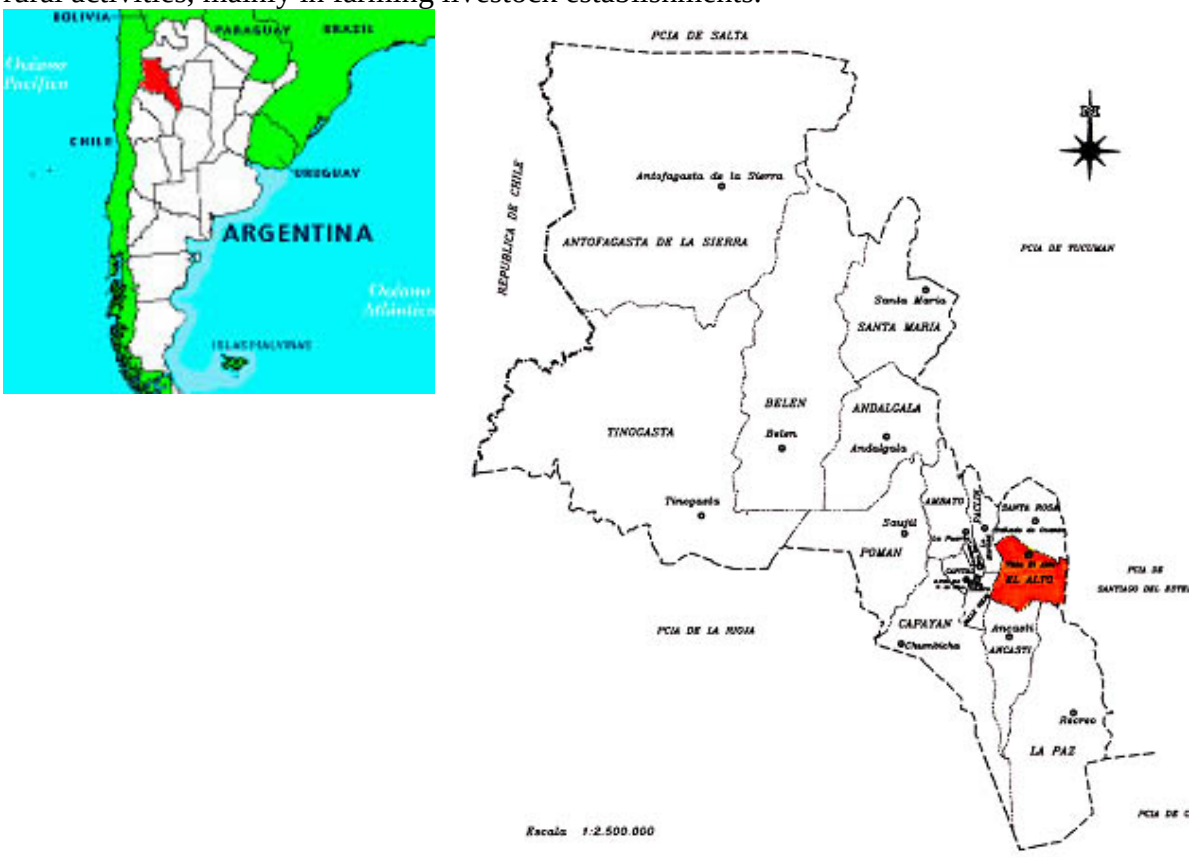
3. AGRO-GEOGRAPHICAL ZONING OVER AN EXPERIMENTAL AREA

The practical operation of agro-geographical zoning has been performed over the territory of Department of El Alto (Province of Catamarca, Argentina) in the perspective of contributing to the knowledge of an area that has not been measured yet in the cadastre.

The province of Catamarca is situated on the northwest of the Republic of Argentina and it has an area of 102,602 square kilometers. The provincial territory has a total population of 265,571 inhabitants (INDEC [*National Institute of Statistics and Censuses*], 1991), and it is made up by 16 departments.

Like any of the Argentinean provinces, Catamarca has its own Constitution in compliance with the representative republican system, according to the principles, declarations and guarantees of the National Constitution. Cadastral legislation in some Argentinean provinces establishes in explicit way, as Catamarca, the necessity to determine homogeneous rural zones as a previous stage to obtain cadastral valuation at a zonal and parceling level.

The Department of El Alto is extended along 2,397 square kilometers, approximately between latitude 28° 10’ and 28° 40’ South, and between longitude 65° 05’ and 65° 37’ West. It has a total population of 2,981 inhabitants (INDEC, 1991), with predominance of rural activities, mainly in farming livestock establishments.



Base Map:
Rodríguez, M. I.,
López, G. del V. (1999)

Figure 1

3.1 Zoning by Coincidence of Generic Regions

The agro-geographical characterization of the Department of El Alto has been attained from the analysis of the information obtained *in situ* through various inspections performed over departmental territory and over the information collected through search and selection of different sources. Some of them are: geographical researches and expeditious agronomic diagnoses provided by the National University of Catamarca; publications of the National Institute of Agronomic Technologies (*INTA, Instituto Nacional de Tecnología Agropecuaria*); bibliographic publications of acknowledged authors about the geographical situation of the province; and consultation to different provincial organisms that possess interesting data about the studied area (Ministry of Production and Development [*Ministerio de Producción y Desarrollo*], Secretary of Planning [*Secretaría de Planeamiento*], Secretary of State of the Environment [*Secretaría de Estado del Ambiente*],

Sub-secretary of Rural Development [*Subsecretaría de Desarrollo Rural*], Direction of Statistics and Censuses [*Dirección de Estadística y Censos*], among others).

The departmental relief corresponds to Sierras de Ancasti–El Alto, that integrate the orographic unity called Sierras Pampeanas. From West to East, it is distinguished (Sayago, 1983) a strip of summit peneplain, a fractured slope and a pedemountain eastern plain. A small sector situated on the north is classified as pedemountain northern plain.

The phytogeographycal description (Morlans, 1995) distinguishes, on the one hand, Chaco Serrano with shrub-like pastureland floor in the western strip and with wood floor in the western slope, and on the other hand, Semiarid Chaco Serrano in zones of slope and eastern plain.

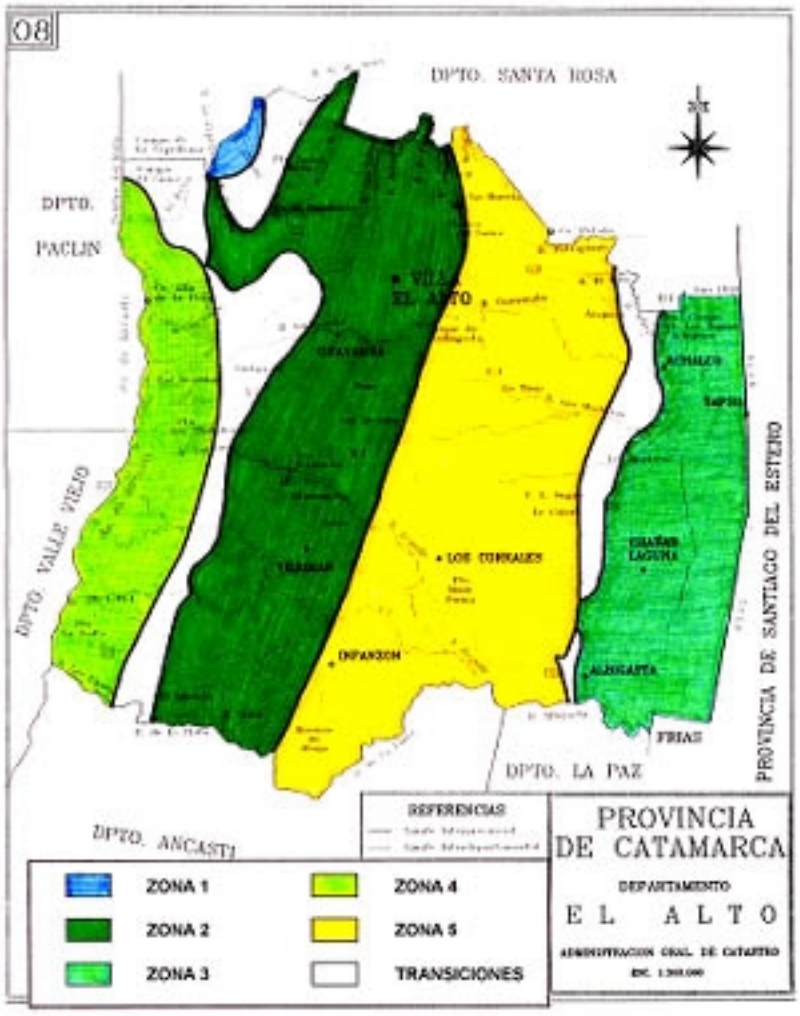


Figure 2.

The elaboration of relief and phytogeographical maps allows the analysis of the zones that result from the superposition of both to be done, differencing in the map in Figure 2 five agro-geographical zones and some white areas that represent transitions, that is, areas that due to their characteristics present problems for their assignation to one or another zone. Transitional areas require more detailed studies in order to include them into neighboring zones or to define new zones, depending on the observation of more similarities than disparities in relation with their neighboring zones.

3.2 Zoning by classification of LANDSAT TM images

The method of association of sites for the determination of zonal boundaries requires the application of mathematical and statistical algorithms that allow the spatial variation of critical attributes of the territory studied to be considered.

Satellite images in digital format permit the performance of the territorial zoning by means of the method of association of sites. This application is now possible because of the computer analysis techniques for the statistic association of homogeneous groups of land covers by examining the reflectance of each pixel.

The digital image processing of a Landsat TM image supplied by the National Commission of Spatial Activities of Argentina [*Comisión Nacional de Actividades Espaciales*], corresponding to path 230, row 80, date 07-16-1997, performed with software Idrisi (Clark University, Massachusetts, USA), has permitted the obtention of the agro-geographical zoning of the Department of El Alto (Catamarca, Argentina), based in procedures of supervised classification with maximum likelihood classifier.

The false color composite image, between bands 2, 3, 4 (Figure 3.1) corresponding to the territory of interest, illustrates some its distinctive aspects. In the west, the peneplain at the top of the Sierras “Ancasti – El Alto” (more than 1,200 meters over the sea level). Toward the east, the mountains slope down to the eastern plane, at 300 meters over the sea level. In the pendent sector two different environments can be recognized: the high lands where vegetation is more dense, and lower arid lands, in correspondence with rain, which decreases from west to east. The image shows regular shapes of parcels, particularly in the eastern plane, assigned to crops.

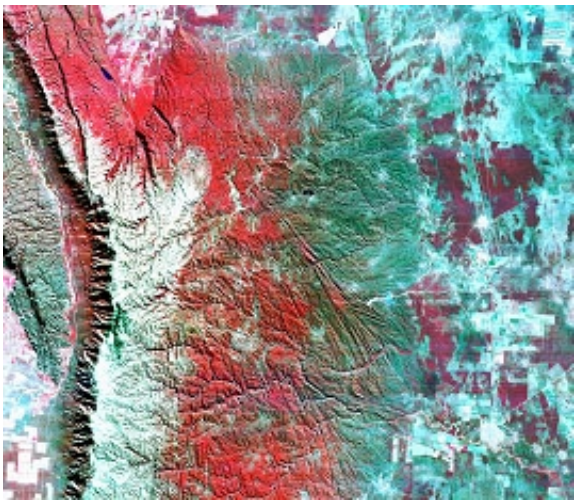


Figure 3.1

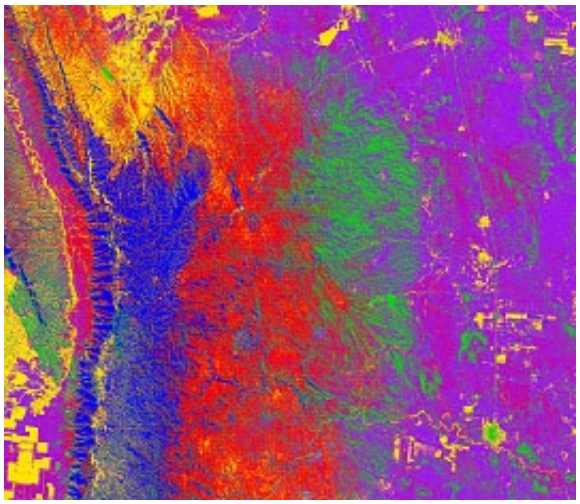


Figure 3.2

In order to establish what compositions could result more suitable attending their best informative contents, the Optimum Index Factor –OIF- has been computed for each one (Chuvieco, 1995). The composite image between bands 1, 4, 5, corresponding to the highest OIF, has been taken as the basis for the supervised classification by the maximum likelihood classifier, obtaining the results shown in Figure 3.2.

In order to compare the zone boundaries obtained from the supervised classification (method of association of sites) with the approximate zoning by coincidence of generic regions, the satellite image has been georeferenced with root-mean-square error (RMS) < 1, the classified image has been graphically superposed with a base map of the Department of El Alto (Cadastre General Administration of Catamarca [*Administración General de Catastro de Catamarca*], 1998), and the zone boundaries were outlined, as shown in Figure 4.

4. RESULT ANALYSIS AND CONCLUSIONS

Agro-geographical zones are defined according to the analysis and weighting of diverse attributes, such as climate, type of soil, topography, hydrology, prevailing agronomic use, and others, answering in a general way to the patterns of formal geographical region. In consequence, these zone delimitations can be resolved by the methods provided by geography, as zoning by site association or zoning by coincidence of generic regions.

The experimental application of both methods over the territory of the Department of El Alto, in the province of Catamarca (Argentina), allows the affirmation that the determination of zone boundaries by coincidence of generic regions results usually approximated, depending on the rigorousness degree of the compiled geographical studies, which in general correspond to different dates, authors, and objectives. In this way, compiled information habitually results insufficient to determine inter-zonal variations,

requiring continual checking on the territory in study in order to avoid serious errors and to find the solution in undetermined areas that appear as transitions.

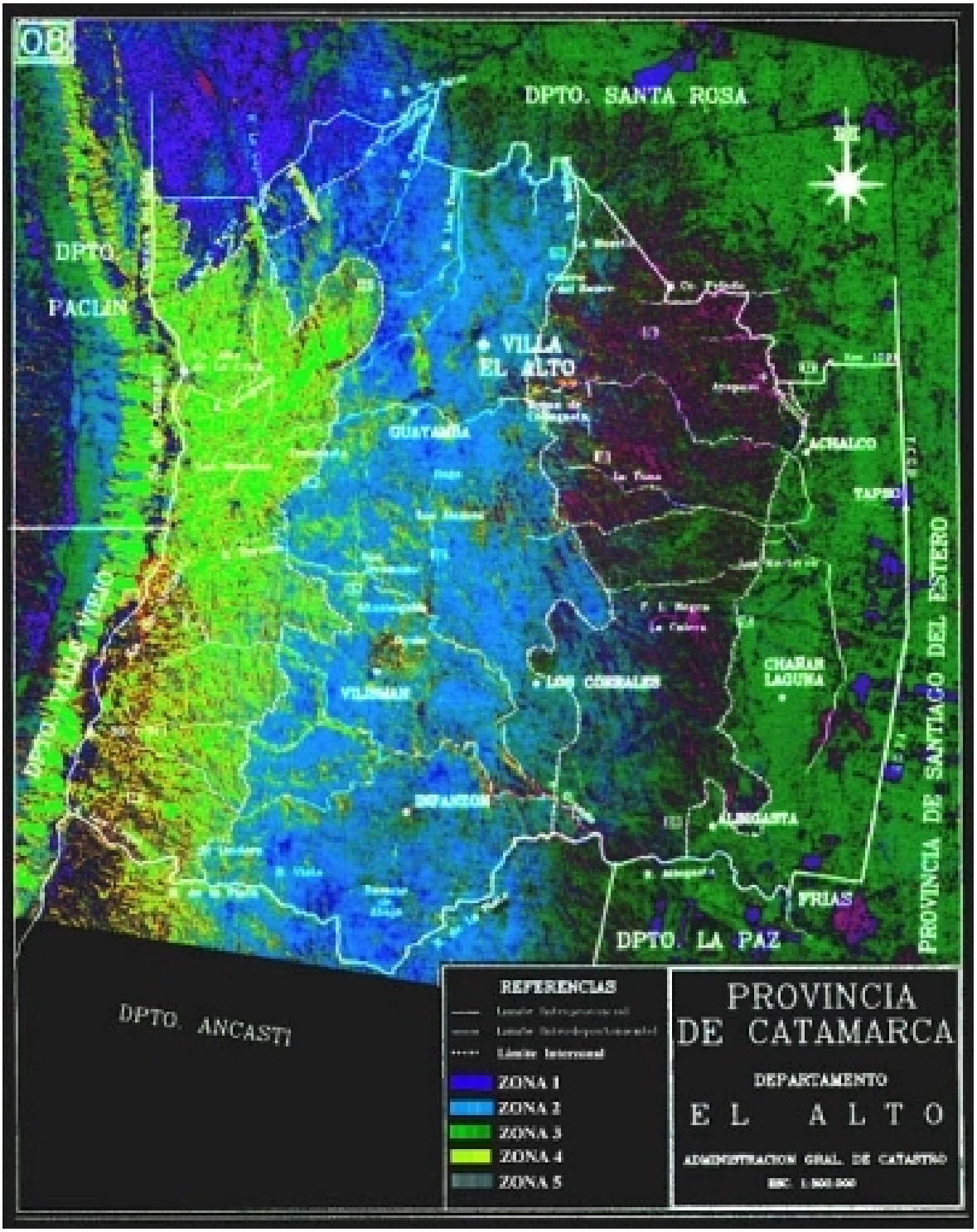


Figure 4.

The territorial zoning by statistical association of homogeneous groups of land covers that have similar levels of reflectance tends, on the contrary, to be more accurate, being there observed inter-zonal variations that derive in better defined boundaries. In this case, the zoning is performed according to the classification of spectral information obtained simultaneously and in the same conditions for all the territory in study (image acquisition date). The zoning can also be periodically checked by processing new images in order to detect changes (dynamic phenomena analysis).

Satellite images facilitate the global vision of the territory, exceeding in most cases administrative jurisdiction boundaries. In consequence, considerations can be taken about agro-geographical unities that are prolonged outside departmental boundaries. Besides, the zonal boundaries can be easily laid out on the ground, because the satellite image georeferenciation allows the coordinates corresponding to each point of the territory to be known. Finally, the georeferencied zoning stored in digital form, can be integrated to geographical and land information systems.

Because of what has been previously explained, in order to divide a territory into agro-geographical zones as a basis for economical considerations and planning development, the application of the method of association of sites by supervised classification of satellite images results advantageous. Apart from this, zonal delimitations by coincidence of generic regions, based in traditional studies, may be restricted to expeditious determinations.

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