7.1. Rule-based image processing methods to facilitate the use of remote sensing images in local planning and adaptive management

Objectives

- ?? Develop a methodology allowing local institutions to use satellite imagery for monitoring, evaluation, and adaptive management of their agriculture and natural resources
- ?? Develop a methodology allowing national institutions to provide data sets to local institutions in a format that they can use for their purposes

Materials and Methods

The framework to link image analysis to processes of planning and adaptive management was based on the approach of visions-actions-requests across administrative levels (Beaulieu et al., 2002[10]). The locally derived visions of desired future conditions are used to define questions for monitoring and evaluation (M&E), whereas the actions and the requests are used to formulate questions for action planning. Imagery, combined with other sources of data, is then used to answer two types of questions, such as "How far are we from the desired conditions; why, and how fast are we getting there?" and "Where should we implement such and such management practices?" As a case study, this framework was applied in the municipality of Puerto Lopez, in particular in the indigenous reserve of Humapo and La Victoria in 2001 (Beaulieu et al., 2001)[1], and during the elaboration of the Plan de Desarrollo Municipal.

Image processing methodology, designed for national institutions to use in providing products to local users, was applied on a data set of images of Puerto Lopez, and was also used for training purposes. This geocoded data set included Landsat-4 TM images of December 1987 and January 1988, and Landsat-7 ETM+ images of March 2000, December 2000, and March 2001. We calculated the reflectance at top of the atmosphere (TOA) from the images' digital numbers by taking into account the solar zenith angle and solar irradiance, as well as processing gain and offset coefficients for each spectral band. Then, a relative atmospheric correction was applied to three of the five images, to allow the reflectance values of "pseudo-invariant" areas to be equivalent to those of the two clearest images. Pseudo-invariant image samples were collected in very clear water and forest areas. Image histograms under consistent image windows were also used to verify the success of the correction. In the case of Puerto Lopez, only an additive correction or "shift" in reflectance was necessary.

Meaningful "indices" were calculated from the red and near-infrared (NIR) spectral bands of each of the images through a simple linear transformation of the values in these bands. The axes of the new coordinate system in the Red vs. NIR space are the "soil line" and its perpendicular. The soil line is a diagonal line along which the reflectance values

---

1 Beaulieu, N.; Jaramillo, J.; Fajardo, A.; Peñuela N. 2001. The use of remote sensing imagery in support to participatory natural resource management: A case study in the indigenous reserve of Humapo and La Victoria. Internal report, PE-4, CIAT, Cali, CO. 20 p.

of bare soil samples tend to align. The coordinates along the axis perpendicular to the soil line indicate the distance from this line, and increase with the cover of green or "chlorophyllic" vegetation. These coordinates are equivalent to the Perpendicular Vegetation Index (PVI) formalized by Richardson and Wiegand (1977[2]). The co-ordinates along the axis of the soil line are called the brightness values. We define the resulting new values or "indices" as brightness (BRI) and vegetation (PVI). The combined use of these indices differs from the use of normalized difference vegetation indices, such as the NDVI, because we retain the same information content as with the two initial spectral bands from which they were calculated. The resulting values are in reflectance units (%). This linear transformation is principally done to allow the Red vs. NIR space to be separated by diagonal thresholds through the use of decision rules, rather than by vertical and horizontal ones.

Many of the M&E or action planning questions that can be answered using satellite imagery require mapping of land cover, land use, or their variation through time. However, we believe it is important for the users to be able to derive their own final maps, because questions are different for each of them, and because they can incorporate knowledge that is inaccessible to the image-processing technician. We also think that results from rule-based classification techniques can be easier to interpret than those from automatic, supervised, or unsupervised classifications. For the identification of agricultural areas, it is often necessary to rely on a series of three images taken within 1 year, to avoid confusing very green crops with forests or plantations, or plowed fields with permanently bare areas. In the case of the classification based on a time series of images within the same year, classifications were based on minimum and maximum values of the PVI, the BRI, and the medium infrared reflectance. For multi- and single-date classifications, we derived decision rules through both logical and automatic approaches. The logical approach was based on visual interpretation of images and on the comprehension of the spectral behavior of terrestrial surfaces. The threshold values were then derived from the mean and standard deviation of samples of each class. For the automatic approach, the r-part library of the S+ statistical software was used to analyze a series of pixel values of the samples, and produce a decision tree. We then combined results of the logical rules and the automatically derived decision trees to obtain an adapted set of decision rules, eventually merging classes to obtain a very general classification. This can then be filtered and used to produce a vectorial coverage, which final users can then edit. For example, if agricultural statistics are sought, a knowledgeable person (e.g., an agricultural extension agent) can assign the type of crop to each agricultural area through this editing process.

Results

The questions that emerged from the Plan de Ordenamiento Territorial (POT) and the Plan de Desarrollo Municipal (PDM) are: How much area is being used under agriculture and how fast is the agricultural area increasing? Where is pasture degradation a problem that we could solve through improved varieties and agropastoral systems? Is there any

---

[2] Richardson, A.J.; Wiegand, C.L. 1977. Distinguishing vegetation from soil background information. Photogram Engineer Remote Sens 43:1541-1552.

forest regeneration in the reserves? Where could preventive burning be a good management option?

The time series of three images during 2002-2001 was therefore used as a baseline data set for the 2000-2009 POT, and the 2001-2004 PDM. The images from 1987 and 1988 unfortunately have very close acquisition dates, and in many cases it is not possible to distinguish ripe rice cultures from forest. While a reliable, municipal-wide comparison of land use was not possible between 1988 and 2000, these historical images were useful in forest reserves.

From this time series of images, the following classes were mapped from maximum and minimum values of the PVI, BRI, and medium infrared reflectance:

(1) Permanent water;
(2) Occasional or seasonal water;
(3) Perennial dense vegetation (forests or plantations);
(4) Perennial mediumly dense vegetation (shrubs, young forest plantations, orchards);
(5) Areas managed by burning (generally savannas);
(6) Occasional or seasonal cover of very chlorophylic vegetation (crops or strong vegetation growth during the wet season);
(7) Perennially bare soil;
(8) Occasional or seasonal bare soil;
(9) Sparse vegetation, with perennially high brightness (thus probably low ground cover of leaves, residue, and organic matter, if soils are bright) and chlorophyllic activity;
(10) Sparse vegetation, with perennially high brightness, but variable chlorophyllic activity;
(11) Sparse vegetation, with perennially low brightness;
(12) Sparse vegetation with variable brightness and chlorophyllic activity; and
(13) Irrigated crops or marshes.

Field data collected in 2001 and 2002 are allowing us to verify the accuracy of the general classifications. We are, however, still adjusting decision trees, combining the results of automatic tree generation through S+ with the ones obtained through visual interpretation and our understanding of the spectral behaviour of different land cover types. Extremely high classification accuracies are obtained when tolerating errors between types of grass (sparse vegetation), allowing agricultural areas to fall in either classes 3 or 4, and allowing marshes to fall either in classes 2, 3, 4, or 13. Errors in the classification assignment mostly resulted from a misassignment of field data, because these were acquired at single dates, while the image classification used three dates. In this case, the results of a classification based on the variations of spectral quantities can be more accurate about an area's behaviour than a single date observation in the field. Details about this classification and its validation can be found in Beaulieu et al. (2002[3]).

[3] Beaulieu, N.; Leclerc, G.; Alvarez, M. 2002. Análisis de una serie temporal de imágenes de Puerto López para una clasificación general de la cobertura de la tierra. Internal report, CIAT- Corporación Colombiana de Investigación Agropecuaria (CORPOICA), Cali-Villavicencio, CO. 30 p.

Class 6, when occurring in savannas, can be indicative of areas where preventive burning could be successful in natural reserves, because natural regeneration seems to be taking place during the wet season. However, visual interpretation is necessary to distinguish these areas from agricultural ones. Classes 7, 8, and 9 can be indicative of areas of degrading pastureland.

The algorithms for rule-based classifications were developed in the PCI software and were translated into the freely distributable SPRING software (developed by the Instituto Nacional de Pesquisas Espaciales [INPE], Brazil) in order for the data set and programs to be distributed to a wide variety of users. Training courses were given in July 2002 to CIAT Land Use Project staff, with participants from CORPOICA and the Universidad del Valle. Another course was given in October in Villavicencio, Colombia, to end users in CORPOICA, the Gobernacion del Meta, and personnel from Unidades Municipales de Asistencia Técnica Agropecuaria (UMATAs) of the area and of municipalities. This course was aimed at interpretation and classification of the images rather than on the preparation of the data sets.

Outputs

Satellite images and aerial photographs can make important contributions to local NRM efforts, especially for M&E, and for adaptive management. The use of these images by natural resource managers could be facilitated by networks linking technical professionals and different types of users at different administrative levels, who can also share the costs and responsibilities of acquiring and processing data. Many of these networks exist, or are in the process of creation. We expect the methodological itinerary we provide will allow professionals of different institutions and disciplines to interlink effectively. In 2003, we will train national and regional institutions that can prepare the data sets for local users.

Contributors: Nathalie Beaulieu, Grégoire Leclerc; Gérard De Wispeleare (CIRAD-EMVT); Mauricio Alvarez (CORPOICA)
Collaborator: Joao Pedro Cordeiro (INPE)