Digital processing of Landsat-5 TM data for land use land cover regional mapping

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Abstract – The objective of this work is to present a methodological approach for land use land cover regional mapping, using Remote Sensing and Geoprocessing techniques. The study area, comprised between the geographic coordinates 01° 45' and 08° 20' South Latitude and 44° 00' and 54° 00' West Longitude, is covered by 17 Thematic Mapper (TM) images of Landsat satellite. This methodology consists on the generation of synthetic images (vegetation, soil and shade), through the spectral linear mixing model using the TM bands 3, 4, and 5, to enhance the contrast among targets of interest and to minimize computer processing time during the classification task. This task was performed using the image segmentation algorithm, followed by the non-supervised classification of regions and mapping the pre-defined classes of interest (thematic legend). The mapping result is finally edited by the photointerpreter with the purpose of correcting any classification errors, based on his experience and using available ancillary information (aerial photographs, maps, etc.). The proposed approach is feasible for large areas using TM or other high-resolution data, producing very reliable map, and permitting to update it at any time and to integrate it with other information in the database.

I. INTRODUCTION

The knowledge of the distribution of the types of vegetation cover and its phenological variations is an indispensable aspect for the planning a coherent and efficient policy of sustainable development, as well as for an objective understanding and evaluation of the coexistence of different ecosystems, natural, semi-natural, agricultural, or industrial. The analysis of the phenological variations on a regional level and its inter-relation with the different geographical components (climate, soil, terrain relief, geology, etc.) form part of the necessary information for the understanding of the functioning of the ecosystems on a global scale. Therefore, the knowledge of the current state and the characterization of the terrestrial ecosystems surface are critical requirements for modeling and understanding the global change processes (TUCKER and SELLERS, 1986).

Vegetation cover and land use mapping, in large areas, has been accomplished using Remote Sensing data obtained by satellites, through the visual interpretation of the color composite generally formed by bands 3, 4, and 5 of the "Thematic Mapper" sensor. The resulting maps, obtained in the analogical form, needs to be available in a Geographical Information System (GIS) for wider use. For this, it is necessary to execute digitizing and/or scanning tasks of the maps obtained. This procedure becomes expensive and not adequate for future updates and/or integration with other information, due to introduced geometric errors.

The evolution of image processing softwares, storage capacity, and computer processing velocity, in recent years, have been motivating the development of new methodologies of digital interpretation of high and medium spatial resolution data, especially for large areas. The information obtained can then be integrated with other types of information (cartographic and field data), introduced in a geo-referenced database. However, the conventional digital analysis of Landsat TM data (30 m of spatial resolution) based on classification pixel by pixel, is limited for only taking into account the spectral variation of the scene, losing the potential of the context information of the objects. Besides, this procedure is not adequate for operational use due to the common commission and omission errors of the classification. Recently, new approaches using image segmentation techniques have been quite promising to estimate the deforested areas (BATISTA et al., 1994; ALVES et al., 1996). However, this technique when applied directly to the original bands of the TM images, demands a significant computation time (BATISTA et al., 1994), limiting its use for large areas.

Considering the aspects mentioned above, INPE has been adapting the methodologies previously developed, to this new reality, i.e., the technological progress of geoprocessing techniques, mainly, towards exploring the maximum potential of the System for Processing of Georeferenced Information (SPRING; INPE/DPI, 1999; CÂMARA et al., 1993), with relation to its applicability in several other scientific fields. In this context, to automate the tasks developed in the PRODES project (INPE, 2001), the "Coordenadoria Geral de Observação da Terra – OBT" at INPE has been developing a methodology of semiautomatic interpretation, based on the segmentation of synthetic images and per region non supervised classification, followed by the classification edition performed by the photointerpreter to assure the quality of the final product (DUARTE et al., 1999).

The creation and implementation of the classification edition algorithm provided a great advance in the field of image processing and also brought many benefits for its users. The classification edition solved a great problem that the user had to minimize the classification errors, inevitable, due to a series of factors such as: likeness of spectral response of different targets, heterogeneity of plantation date, etc. After the implementation of this tool, the user with his experience and available ancillary information is able to interfere in the classification results, changing polygons classified erroneously for the correct class and improving the limits of the classified polygons.

Therefore, considering the large area to be mapped and the need of having the information available in a digital database for future analysis, the objective of this work is to present the methodology adapted from DIGITAL PRODES Project, using satellite data and complementary information (cartographic and aerial photographs), for mapping the land cover and land use in the large region defined as the study area.

II MATERIAL AND METHODS

Study Area

The study area, comprised between coordinates 01^o 45' and 08^o 20' South Latitude and 44^o 00' and 54^o 00' West Longitude, is covered by 17 TM scenes.

For this work, the 394 aerial photographs used are spatially distributed in a sampling form throughout the study area. 121 aerial photographs encompassing the whole basin of the Itinga river were also used. All these photographs are in the scale of 1: 25,000 and were used with the objective to support the validation of image classification.

Methodology

The methodology used in this work was adapted from the digital mapping of deforested areas in Amazonia (DIGITAL PRODES; DUARTE et al., 1999).

Generation of the synthetic images

The generation of the synthetic images has a purpose to reduce the dimension of the data to be analyzed, mainly for large areas, as well as to enhance the targets of interest to be mapped. For this, the linear spectral mixing model (SHIMABUKURO and SMITH, 1991) was used to estimate the proportion of the components: soil, vegetation, and shade, for each pixel, using the original bands of the Landsat TM images, generating the corresponding synthetic images: soil, vegetation, and shade. In this work, bands 3 (0.63 – 0.69 μm), 4 (0.76 – 0.90 μm), and 5 (1.55 – 1.75 μm) of TM images were used for generating the synthetic images. The synthetic shade image provides a great contrast between areas occupied with forests (medium amount of shade) and deforested areas (low amount of shade), besides a good separability of themes such as drainage, burned, and regrowth areas. The synthetic soil image has been very useful in the analysis of the areas occupied by savanna ("cerrado") coverage and mainly, enhancing the recently clearcut areas. The synthetic vegetation image enhances the areas occupied by vegetation coverage, and it was also used to discriminate several classes inside the deforested areas (agricultural and cattle raising activities areas, dirty pasture, regrowth areas, etc.).

Segmentation of the synthetic images

The procedure of image segmentation is based on the "region growing" algorithm, where a region is a group of homogeneous pixels linked according to their properties (ZUCKER, 1976). A detailed description of the image segmentation process can be found in BATISTA et al. (1994).

To execute the image segmentation, the user needs to define two parameters: 1) the similarity threshold: minimum distance between the digital values (gray levels) below of which two segments are considered similar and therefore grouped in a unique region; and 2) the area threshold: minimum area to be considered as a region, defined in number of pixels. In this work, it was defined the values 8 and 16 for similarity and area thresholds, respectively.

Generation of the context file and region extraction

To perform the image classification it is necessary to create a context file, where the information are stored: a) per region classification type; b) bands or images utilized; and c) segmented image. The region extraction is a procedure in that the algorithm extracts the statistical attributes (mean and covariance matrix) of the set of regions defined by the segmentation procedure.

Classification of the segmented image

A non supervised classification based on a grouping algorithm (Clustering ") was applied to the segmented synthetic images. Grouping techniques are widely known (DUDA and HART, 1973). The algorithm used in this work, called ISOSEG (BINS et al., 1992), uses the covariance matrix and the vector of mean of the regions to estimate the center of the classes. The user can define an acceptance threshold that is the maximum Mahalanobis distance in that the medium digital value of the regions can be far away from the center of one class to be considered as belonging to this class.

Mapping of the segmented image

After classification of the segmented image, the themes obtained by the classifier are associated to the defined classes in the database, according to the legend previously established for this work, associating a specific color for each thematic class: a) Forest vegetation; b) Non-forest vegetation; c) Regrowth vegetation; d) Selective logging; e) Agricultural and cattle raising activities; f) Dirty pasture; g) Anthropic area; h) Urbanized area; i) Hidrography; j) Forested savanna; k) Arboreous savanna; l) Park savanna; and m) Cloud and shadow.

III OPERATIONAL METHODOLOGICAL PROCEDURE

In this work, each Landsat TM scene was associated to a database in the software SPRING. To demonstrate the operational use of this approach, adopted in this work, the TM scene, path 223 / row 62, corresponding to the area located in the northeast of Tucuruí reservoir, in the Pará State, where the predominant vegetation cover is forest type.

Firstly, the vegetation, soil, and shade synthetic images were generated through the linear spectral mixing model. The resulting synthetic images were resampled for the resolution of 60 m x 60 m, considering the scale of 1: 250,000 as the final map format. Based on the experience acquired in the DIGITAL PRODES project, this resampling procedure minimizes the computer processing time without harming the classification result.

Following, the shade synthetic image was segmented, using the thresholds 8 (similarity) and 16 (area). The generated segmentation lines over the shade image and over the RGB (543) composite image, indicate that there is no loss of information when reducing the data to be analyzed.

As commented previously, the classifier ISOSEG considers the segmented polygons as elements on the terrain to be classified, i.e., one polygon is an individual area that will be considered for naming the classes. In other words, even if the polygon contains subclasses of land use, it will be classified as a unique thematic class, since that, in the segmentation it was considered like it. For that reason, the classification is nothing else than of grouping the polygons into thematic classes according to the homogeneity of gray levels, considered by the segmentation algorithm.

It is important to remind that in the mapping phase (operation accomplished soon after the classification phase) many of the areas are grouped into a same class, because this is a phase when the analyst interferes in the classification results, i.e., it is made a regrouping, in new classes referring to the themes of the pré-defined legend. However, it is not possible to eliminate all the poligonalization errors, like the limits between two consecutive classes. This kind of error is corrected during the classification edition phase.

The themes of forest vegetation, hidrography, and the deforested areas were mapped using the shade synthetic image, in the area with predominance of forest coverage. The selective logging areas were mapped visually over the areas occupied with forest vegetation theme, using the RGB color composite of TM and mainly the soil synthetic image, which enhances the set of small deforested areas. In the area of savanna region, the soil synthetic image was also used.

Another important fact that contributed significantly for the automated interpretation of current land use, was the possibility that the SPRING allows to the photointerpreter to perform successive mosaics, bringing from the different partial classifications only those classes that represent certain theme of interest. In the last analysis, the system allows to compose the final map in such a successively way, in that the new incorporated themes do not alter those considered previously, i.e., the new themes that are going to be incorporated, occupy only the empty spaces available in the information layer (PI) which is being edited for producing the final map.

Later on, after separating the themes mentioned above, the soil and vegetation synthetic images were used to discriminate areas occupied with dirty pasture, regrowth vegetation, and agricultural and cattle raising activities areas. The areas occupied with savanna vegetation type were separated from those of forest vegetation areas, using the ancillary information of Vegetation Map of Brazil (IBGE/IBAMA), and the NOAA / AVHRR images mosaic (August 1993). The savanna region were mapped into the following classes: Forest Savanna, Arboreous Savanna, and Park Savanna.

The classification edition phase is very important to assure the quality of the final map. In this phase, the user, based on his experience and with support of available ancillary information (aerial photographs, maps, etc.), can correct the commission and omission errors generated by the classifier, besides improving the limits of the classified polygons.

The procedure to perform the land cover land use mapping, as presented for the Landsat TM 223/62 image, through the segmentation and classification of the synthetic images, allowed to discriminate several classes of the established thematic legend, according to the corresponding Final Map showed in figure 1.

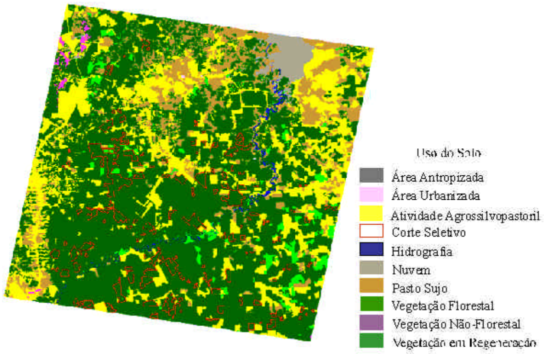

Fig. 1. Final map of the TM image (path 223/row 62) obtained through the methodology utilized in this work.

Finally, this procedure was applied for all the other 16 TM images, that cover the study area, obtaining the land cover land use map for each one of them. Following, these individual classifications were mosaic for the entire study area and the thematic legend was adapted and generalized for a regional visualization purpose as showed in figure 2.

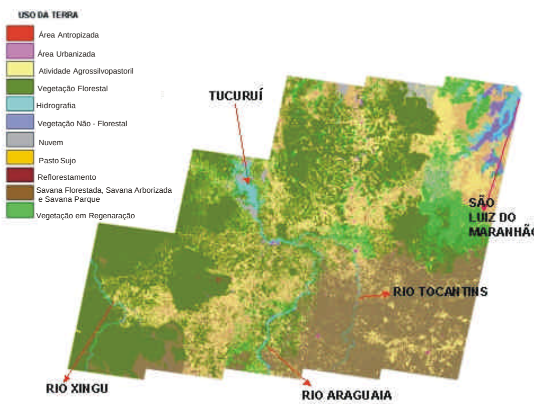

Fig. 2. Land cover land use map of the study area.

IV FINAL CONSIDERATIONS

The methodology utilized showed to be adequate for this work, allowing to map the vegetation cover and land use in this large region.

The classification edition was performed by the photointerpreter directly on the computer monitor, considering the scale 1 : 250,000 for generating the final product. If necessary, the classification edition can be performed with more details.

The aerial photographs were very useful especially to define the land use classes (dirty pasture, agricultural and cattle raising activities areas, and regrowth areas).

The computer software SPRING allows to generalize or to detail the final classification map in a sequential manner, allowing therefore that this map can be updated and/or corrected anytime by the photointerpreter.

The final map in the digital format, georeferenced in a database, can be integrated with other types of information, being very useful for the "Zoneamento Ecológico e Econômico (ZEE)".

This Methodology can be adapted and applied for other different objectives and/or other large regions with different characteristics.

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