Mapping and monitoring land cover in Corumbiara area, Brazilian Amazônia, using JERS-1 SAR multitemporal data

Yosio E. Shimabukuro
Raimundo Almeida-Filho
Tatiana M. Kuplich
Ramon M. de Freitas

Instituto Nacional de Pesquisas Espaciais (INPE)
Av. dos Astronautas, 1758
CEP 12227-010, São José dos Campos, SP, Brazil
E-mail: {yosio, rai, tmk, ramon}@dsr.inpe.br

***Abstract*- This paper discusses the use of a JERS-1 Synthetic Aperture Radar (SAR) time-series for mapping and monitoring land cover in a test site in the region of Corumbiara, Rondônia State, western Brazilian Amazônia. In order to support JERS-1 data analysis, land cover maps were obtained by digital classification of Landsat TM images acquired from 1993 to 1997 period, following a procedure based on image segmentation, unsupervised classification, and post-classification image edition. The comparison of these products with JERS-1 images shows that clean deforested areas are well identified presenting a low backscattering response as expected. However areas that have been cleared and even burned but with remaining forest material left on the ground present high backscattering response opposed to expected. Considering these observations and user interpretation expertise, JERS-1 SAR images can be used to map and monitor land cover changes in Amazonia.**

Keywords: JERS-1 data, land cover map, multitemporal analysis, digital classification, Amazonia region

I. INTRODUCTION

There is an increasing need for accurate mapping of forest conservation status. Since 1988 Brazilian Amazonia is monitored through the PRODES (Brazilian Estimate of Deforestation) Project [1], which results have become available online, including yearly deforestation rates (http://www.obt.inpe.br/prodes/index.html). Maps and rates of deforestation are estimated after interpretation of Landsat Thematic Mapper (TM) images and, although the PRODES have been conducted successfully, it relies on optical remote sensing data, subject to the near-constant cloud coverage over the tropics.

Synthetic Aperture Radar (SAR) data are independent of weather conditions and are related to canopy structure and shadowing [2]. Because its sensibility to forest structure, L-band SAR data seems to be an alternative source for mapping deforestation areas especially in the region where optical data is restricted by cloud cover.

The deforestation process can follow different methods, but it is common the gradual removal of vegetation by chain saws, machinery or fire. The presence of woody material on the ground will produce an enhancement of the SAR response as discussed by Stone and Woodwell [3] and Almeida-Filho et al. [4]. Almeida-Filho et al. [4] used L band JERS-1 (Japanese Earth Resources Satellite) SAR data for the mapping of deforestation in Amazonia, using techniques that enhanced temporal changes occurred in the land cover. Results showed a difficult detection of initial stages of deforestation (when residual trees still remain on the ground), although "complete" clear-cuts were detected accurately.

This research follows a previous work, where correlation between optical and SAR data for the same study area were estimated [5]. As results of the quantitative approach were very promising, we followed with a qualitative analysis in a multi-temporal time series. Then the objective of this paper is to understand all the variables involved in deforestation mapping as to propose the operational use of SAR data for this task.

II. STUDY AREA

The study area is located in the south of Rondônia State, western Brazilian Amazônia (Figure 1), and comprises approximately 4,000 km^2. The region is mainly covered by dense tropical forest that has been partially cleared over the past thirty years.

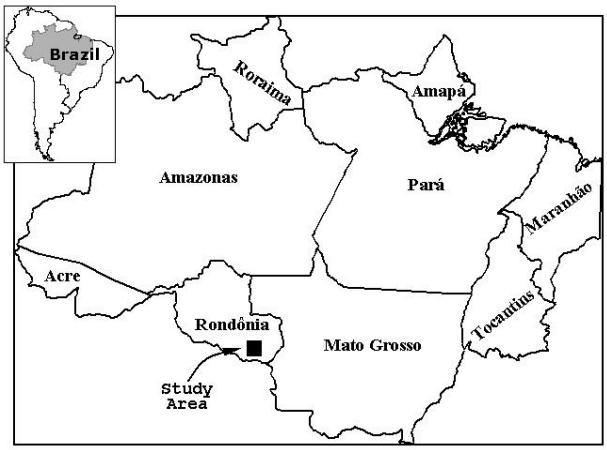

Figure 1. Location of the study area.

III. IMAGE PROCESSING AND INTERPRETATION

Ten JERS-1 SAR and five Landsat Thematic Mapper (TM) images were acquired between 1993 and 1997 (Table 1). The TM images were used to support the interpretation of the multitemporal SAR scenes. The JERS-1 SAR operated in L-band frequency (wavelength of 23.5 cm), with HH polarization and right-looking off-nadir angle of 35 degrees. The ground resolution was 18 m in both range and azimuth directions, and the swath width 75 km. The ten JERS-1 images selected for this investigation were processed to standard level 2.1, i.e., 16 bits ground range, 3 looks and a pixel spacing of 12.5 x 12.5 m. Several adaptive and non-adaptive filters were tested to reduce speckle noise in the SAR images. The best results in terms of minimum loss of textural information and preservation of edges, estimated by visual inspection, were obtained with a 5 by 5 window Gamma Filter as implemented in the ENVI software [6].

Based on satellite ephemeris, the 1993 TM image was geometrically corrected to the Universal Transverse Mercator (UTM) coordinate system, using a first-degree polynomial algorithm. This scene was used as reference to co-register the other TM images. In all cases, the co-registration accuracies were better than 0.8 pixels. Similarly, all JERS-1 SAR images were also co-registered to the TM images and resampled to the same spatial resolution (pixel 30 m x 30 m).

Figure 2 shows the land cover map of the study area derived from Landsat TM images acquired between 1993 to 1997 time period. It was obtained by digital classification following the procedure presented by Shimabukuro et al. [7], which is based on image segmentation using a region growing algorithm, followed by unsupervised classification, and post-classification image editing. This procedure minimizes the omission and commission errors of the classification according to Almeida-Filho and Shimabukuro [8]. Land cover classes included: (i) primary forest, (ii) savanna, (iii) deforested (clear-cut) areas, and (iv) flooded vegetation. These data allowed to estimate temporal changes in the land cover classes (such as classes of burned grassland and burned forest converted to deforested areas), as well as the increment of deforested areas from one year to another.

Visual inspection of JERS-1 SAR image acquired on 08 August 1997 showed a high contrast between forest (medium gray), flooded vegetation (bright gray), and cleared areas (dark gray) as compared to Landsat TM acquired on 01 August 1997 (Figure 3). The areas recently burned, seen at the TM image acquired on 13 September 1995, as dark purple, appear as bright gray in the SAR data, being detectable easily by an interpreter (Figure 4). In a careful inspection of the temporal JERS-1 SAR data, the history of clearings seen in Figure 2, with the approximate age of cleared areas, can also be observed. Then areas cleared initially by burning and with remaining biomass on the ground are seen by bright tones, although dark gray areas are related to bare soil (prepared for crop plantation), pastures or complete deforestation. In addition, the JERS-1 images acquired in 1997 allowed to observe some deforested areas incremented from 1996 to 1997 time period.

TABLE 1: JERS-1 SAR and Landsat TM images used in this study

JERS-1 SAR Images	Landsat TM Images
30-September-1993	19-June-1993
09-February-1994	09-August-1994
04-August-1994	13-September-1995
18-October-1995	13-July-1996
25-May-1996	01-August-1997
17-November-1996	
29-March-1997	
12-May-1997	
25-June-1997	
08-August-1997	

Then if an initial assessment of deforestation (or bare soil areas) is available from optical images, such as PRODES project information, a monitoring procedure can be sought with SAR images preferable from dry season, where the influence of water in soils and vegetation is negligible.

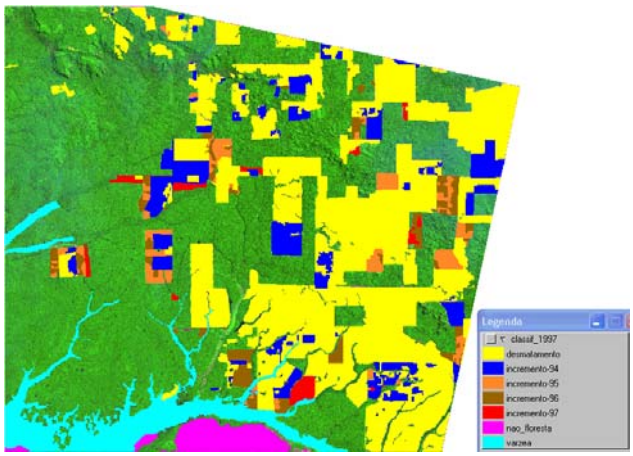

Figure 2: Land cover map based on classification of Landsat TM time series.

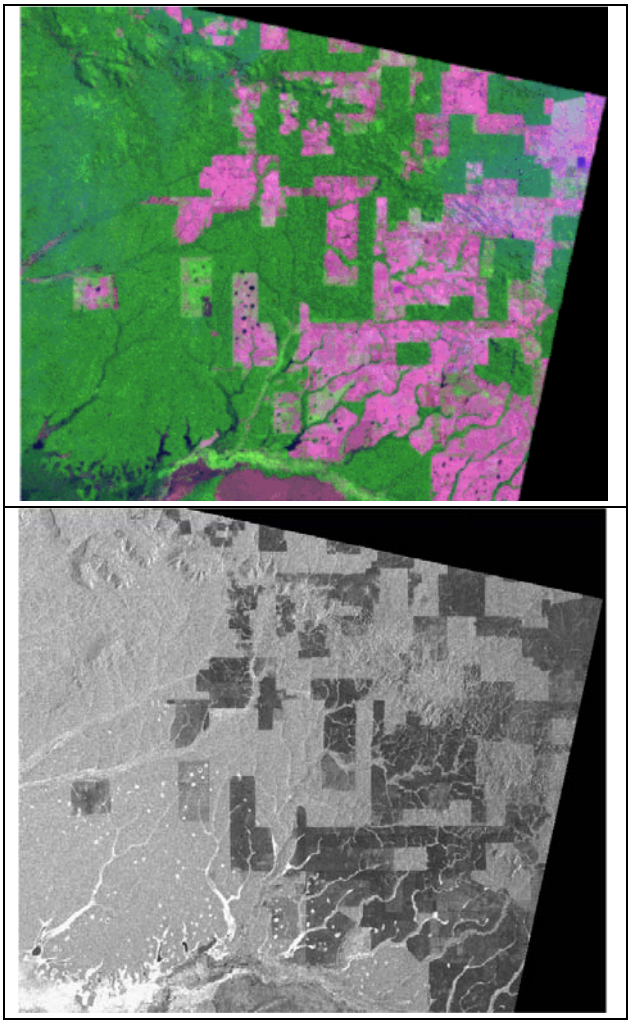

Figure 3. Landsat TM image (01 August 1997) and JERS-1 SAR image (08 August 1997).

IV. CONCLUSION

JERS-1 SAR images showed that clean deforested areas are well identified presenting a low backscattering response as expected, while areas that have been cleared and even burned but with remaining forest material left on the ground present high backscattering response opposed to expected. Considering these observations and user interpretation expertise, JERS-1 images can be used to map and monitor land cover changes in Amazonia. Then using an initial assessment of deforestation as available in the PRODES website, the JERS-1 SAR data is a useful source of information for monitoring deforestation activities in Amazonia considering that its acquisition is independent of weather condition.

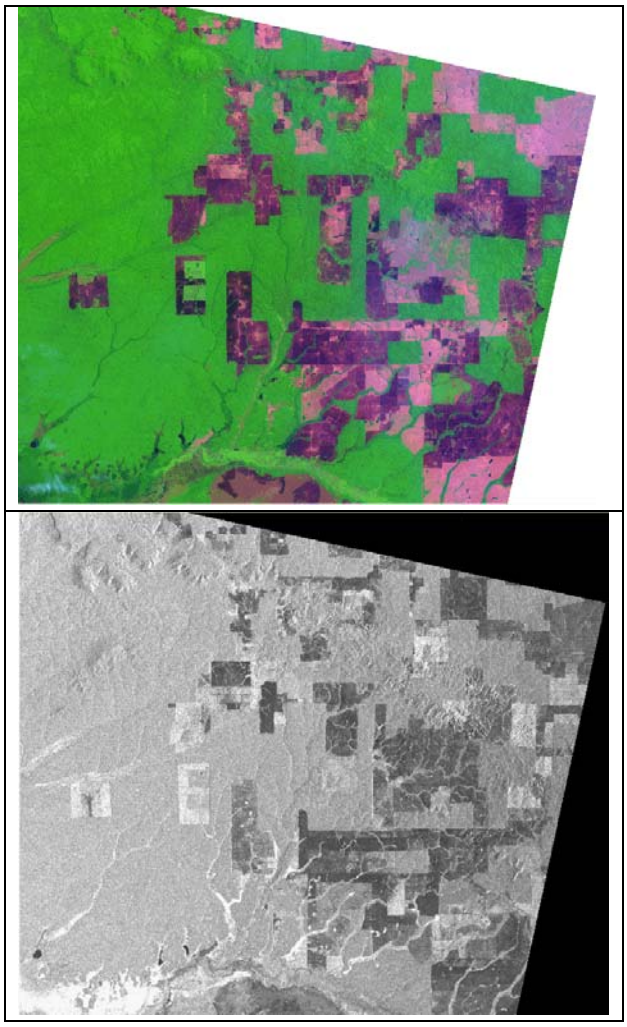

Figure 4. Landsat TM image (13 September 1995) and JERS-1 SAR image (18 October 1995).

V. ACKNOWLEDGEMENT

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