USE OF LANDSAT TM FRACTION IMAGES TO QUANTIFY THE OPTICAL AND SAR DATA RELATIONSHIPS FOR LAND COVER DISCRIMINATION IN THE BRAZILIAN AMAZONIA

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ABSTRACT:

This paper presents a comparison between L-band HH JERS-1 SAR and Landsat TM data for land cover assessment in an Amazonian test site. For this, a study area located in the south of Rondônia State, western Brazilian Amazonia, was selected. The Landsat TM data acquired on August 1st 1997 were converted to vegetation, soil, and shade fraction images, using a Linear Spectral Mixing Model. These fraction images are produced to enhance different characteristics of land cover, expressed as different mixtures of a few number of image components. The JERS-1 data acquired on August 08th 1997 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 m. To compare JERS-1 and TM fraction images, a regression analysis technique was used. The multiple regression analysis showed coefficient of determination (R^2) of 0.86 between SAR and the fraction images. The visual inspection of JERS-1 SAR image showed the high contrast between forest (medium gray) and cleared areas (dark gray). There is a direct relationship between SAR and shade fraction images and an inverse relationship between SAR and soil fraction images. Based on these relationships, it can be pointed out the utility of SAR data as an alternative data source for land cover classification in the Amazonian region.

1. INTRODUCTION

The complementary use of optical and Synthetic Aperture Radar (SAR) data for the definition of different land cover/land use classes has been showed by different authors (e.g. Rignot et al., 1997; Kuplich et al., 1997). The quantification of such a complementary use, however, has not been accomplished yet. Attempts to quantify optical and SAR image relationships were made by Imhoff et al. (1986), who found "extremely low correlations between the radar image patterns and any of the individual Landsat/MSS bands". Obviously such a conclusion cannot be generalized to all land cover/land use types found in a tropical landscape. SAR bands in different wavelengths and polarizations also show potential for discriminating land cover types (Hoekman and Quinones, 2000), although the knowledge about their capabilities is not as robust as for the optical data.

The theory about optical and radar interaction with forest canopies evokes the structure of vegetation as the main factor responsible for the response recorded by both type of sensors (Imhoff, 1995; Lu et al., 2004). The term "structure of vegetation" is used here as proposed by Parker (1995), to refer to the horizontal and vertical arrangement of canopy components, from leaves and branches to the different strata of individuals, including gaps and emergent trees that might break the surface of forest canopy. Species differences in growth form and shade tolerance, as well as succession stage, produce, invariably, shadowing effects at the surface of forest canopies (Asner and Warner, 1995).

In tropical areas, Landsat Thematic Mapper (TM) fraction-images derived from linear spectral mixing modeling have proved to be an adequate source of information for discriminating land cover types, particularly forested and clear-cut areas (Adams et al., 1995; Shimabukuro et al., 1998).

Because its sensibility to forest structure (Weishampel et al., 1996), L-band SAR data seem to be an alternative source for mapping deforestation areas especially in the region where optical data is restricted by cloud cover.

In this work statistical analysis was performed to investigate the relationships between JERS-1 (Japanese Earth Resources Satellite) /SAR and Landsat/TM fraction images, for different land cover/land use types.

2. STUDY AREA

The study area is located in the south of Rondônia State, western Brazilian Amazonia (Figure 1), and comprising approximately 4,000 km^2. The area is mainly covered by tropical forest that has been partially cleared over the past thirty years. Figure 2 shows the 1997 TM image (R5G4B3) and the land cover map of the study area derived from this image.
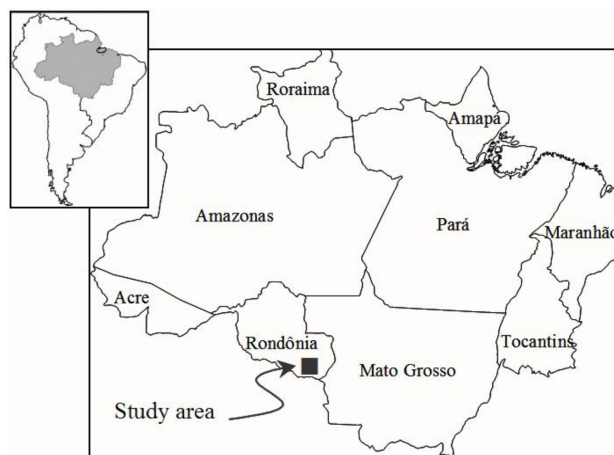

Figure 1. Location of the study area.

The land cover map of the area (Figure 2) was obtained by digital classification using the procedure presented by Shimabukuro et al. (1998), which is based on image segmentation using region growing algorithm, followed by unsupervised classification, and
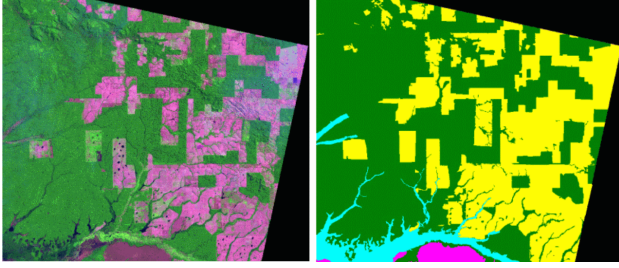
Figure 2. a) Landsat TM (R5G4B3) acquired on 1st August 1997 and b) corresponding land cover/land use map. The classes considered include: forest(green) , savanna(pink) , deforestation(yellow), and flooded forest(blue).

post-classification image edition. This procedure minimizes the omission and commission errors of the classification (Almeida-Filho and Shimabukuro, 2002). The classes considered with corresponding colour code in Figure 2.

3. REMOTE SENSING DATA AND PROCESSING

JERS-1 SAR image acquired on 08 August 1997 over the study site and the corresponding Landsat TM images acquired on 01 August 1997 were used in this study.

The JERS-1 SAR operated in L-band frequency (wavelength of 23.5 cm), with HH polarization and west-looking off-nadir angle of 35 degrees. The ground resolution was 18 meters in both range and azimuth directions, and the swath width 75 km. The JERS-1 data 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.

Based on satellite ephemeris, the Landsat-5 TM image was geometrically corrected to the Universal Transverse Mercator (UTM) coordinate system, by using a first-degree polynomial algorithm. The co-registration accuracy was better than 0.8 pixels. After this, the JERS-1 SAR image was co-registered to the Landsat TM image and resampled to the same spatial resolution (pixel 30 m x 30 m).

JERS-1 SAR DNs (digital number) were converted to backscatter coefficient (σ°) using the following equation (Rosenqvist, 1996; Shimada, 2001):

$$\sigma^\circ = 10\log_{10}(\frac{\sum DN^2}{n}) + CF \qquad (1)$$

where DN = digital number of image pixels; n = number of pixels sampled and CF = calibration factor. The calibration factor was -85.5 [dB] according to the processing date of the SAR image (Shimada, 2001) .

In the next step, the Landsat TM data were converted to vegetation, soil, and shade fraction images, using a Linear Spectral Mixing Model (Shimabukuro and Smith, 1991). These fraction images are produced to enhance different characteristics of land cover, expressed as different mixtures of a few number of image components. Thus, the vegetation fraction image highlights

the vegetation cover conditions; soil fraction image highlights areas of bare soils; and shade fraction images highlights shades in the canopy, which express differences on the forest cover types (Shimabukuro et al., 1998). These fraction images were considered adequate for comparing with the SAR responses for land surface characteristics as performed in this work.

To evaluate the JERS-1 and TM fraction images relationships, a regression analysis was performed. Two hundred and twenty (220) samples (10 x 10 pixels) randomly distributed over all classified land cover types were acquired on the JERS-1 and TM images. The relationships between JERS-1 SAR and individual TM fraction images were also analyzed.

For the regression analysis, JERS-1 SAR backscatter values were considered as the dependent variable and TM-derived vegetation, soil, and shade fraction image values were considered the independent variables. In addition, a visual comparison between SAR and TM fraction images was performed to evaluate the potential of SAR information for land cover discrimination in the Amazonian region.

4. RESULTS AND DISCUSSION

The multiple regression analysis showed coefficient of determination (R^2) equal to 0.86 (Figure 3). (R^2) value was obtained considering all 220 samples acquired in JERS-1 SAR and Landsat TM fraction images (vegetation, soil, and shade).
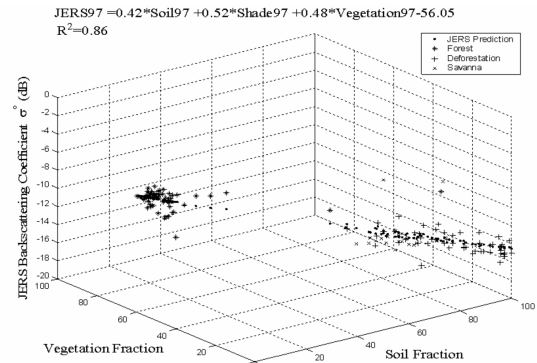

Figure 3. Multiple regression results for SAR and TM fraction images.

The analysis of SAR and individual TM fraction images showed $R^2 = 0.85$ for soil fraction, $R^2 = 0.80$ for shade fraction, and $R^2 = 0.76$ for vegetation using the same 220 samples. These results also confirmed the previous multiple regression analysis.

Figure 4 presents the SAR backscattering values for the land cover types. Figures 5, 6, and 7 allowed a better understanding of the SAR backscatter values and TM fractions relationships. In Figure 4 the clear difference between forest and deforestation samples for SAR image can be observed.

The scatterplot of shade fraction and SAR images (Figure 5) shows higher values for forested cover in both shade fraction and SAR responses. For deforestation class, values in shade fraction and SAR images are lower and, for savanna class, with less dense vegetation and some soil response, values are intermediate.

The scatterplot of soil fraction and SAR images (Figure 6) shows inverse results as showed for Figure 5, i.e., lower values in soil
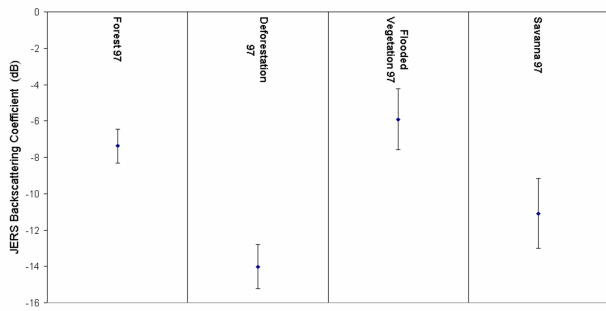
Figure 4. 1997 JERS-1 SAR Backscattering values for the samples of the land cover classes.
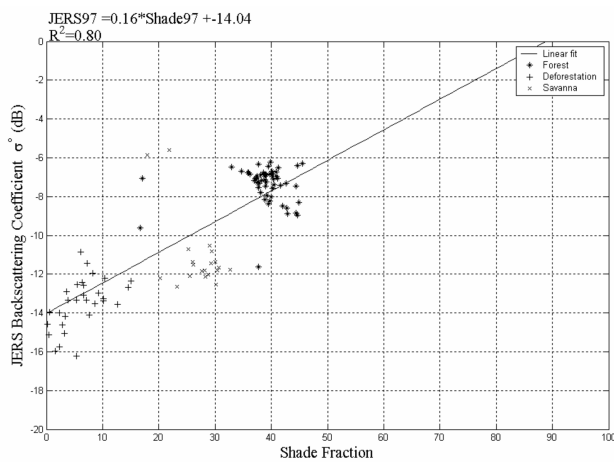

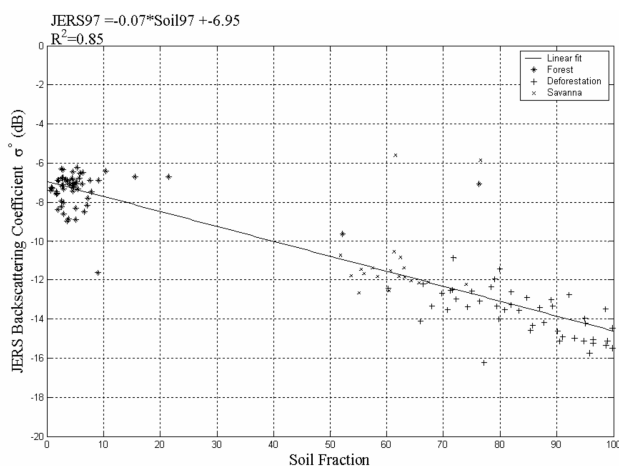Figure 5. Linear regression between JERS-1 SAR and shade fraction image.

Figure 6. Linear regression between JERS-1 SAR and soil fraction image.

fraction and higher values in SAR image for forested cover. For deforestation class, values are higher for soil and lower in SAR images and, for savanna class, with less dense vegetation cover and some soil response, values are intermediate.

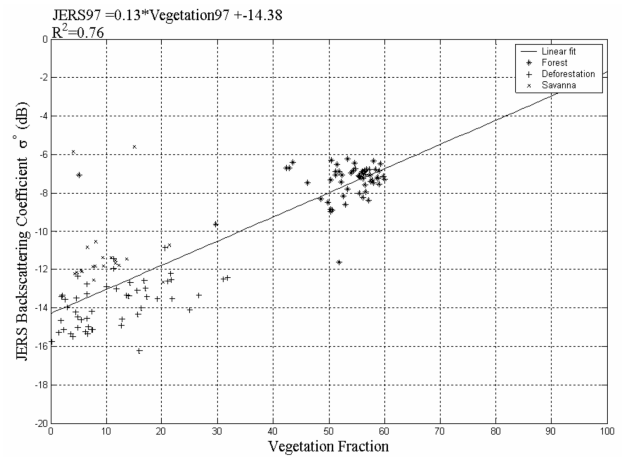The scatterplot of vegetation fraction and SAR images (Figure

Figure 7. Regression between JERS-1 SAR and vegetation fraction image.

7) shows similar results as showed in Figure 5, i.e., higher values for forested cover, in both vegetation and SAR responses. For deforestation class, values in vegetation and SAR images are lower and, for savanna class, with less dense vegetation and some soil response, values are intermediate.

These results demonstrated that JERS-1 SAR responses are strongly related to land surface characteristics as represented by TM fraction images.

Visual inspection of JERS-1 SAR image clearly shows the high contrast between forest (medium gray) and cleared areas (dark gray). Figure 8 shows the JERS-1 SAR image (a) and vegetation (b), soil (c), and shade (d) Landsat TM fraction images. A direct relationship can be observed between SAR and shade fraction images and an inverse relationship between SAR and soil fraction images. Based on these relationships, it can be pointed out the utility of SAR data as an alternative data source for land cover classification in the Amazonian region.
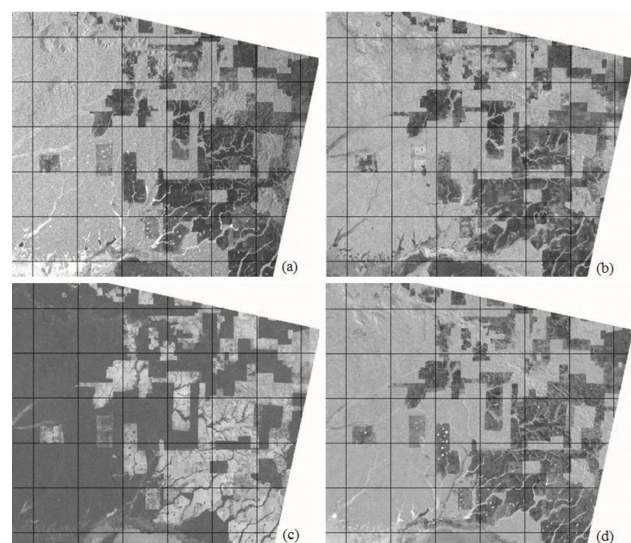

Figure 8. a) JERS-1 SAR and b) vegetation, c) soil, and d) shade fraction images derived from Landsat TM data acquired in August 1997 (grid is 10 x 10 km, North is to the top).

5. CONCLUSIONS AND FUTURE WORK

Multiple regression analysis showed coefficient of determination (R^2) of 0.86 between JERS-1 SAR and Landsat TM fraction images. The results showed that JERS-1 SAR response is strongly related to land surface characteristics as represented by the TM fraction images. The shade fraction image presented very similar visual characteristics when compared with JERS-1 SAR data. This similarity presents a potential use of future ALOS/PALSAR data for mapping deforestation areas in the Amazonia region. The availability of extended polarization possibilities in the PALSAR data will be subject of further work.

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