AMAZON DEFORESTATION MONITORING SYSTEM WITH ALOS SAR COMPLEMENTARY DATA

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ABSTRACT:

Deforestation monitoring for the Brazilian Amazon has been carried on by INPE since 1988, under the PRODES program, and recently, the DETER was created for faster response. The data from both programs have been used by IBAMA for operational purposes and law enforcement. However, optical sensors are limited by the presence of clouds. The ALOS was launched in 2006, and its data became available to IBAMA thought the JAXA's ALOS Kyoto and Carbon Initiative project. The study area is located in the State of Para, Brazil an area of forest facing a growing pressure of deforestation. The ScanSAR strip mode image was geo-rectified and subset and DN image values were converted to the normalized radar cross section (σo), in dB, with a calibration factor of -83 dB. The SRTM data were used to exclude the classified areas that could present relief effects on the ScanSAR image. The mean s value for recent deforested area was -5.315dB and the mean so value for preserved native forest was - 7.569dB. The executed methodology, using a threshold to classify new deforested areas, has a good potential to be the base of a semiautomatic detection system for operational purposes, using ScanSAR images. This system has potential to produce data that could complement the information already available from optical sensor satellites.

1. INTRODUCTION

1.1 Historic and Present Situation of Brazilian Amazon Region Forest Monitoring

Deforestation monitoring for the Brazilian Amazon has been carried on annually by INPE (National Institute for Space Research) since 1988, under the PRODES (Brazilian Amazonian Forest Monitoring by Satellite) program. More recently, the DETER (Real Time Deforestation Detection System) program was launched to give a faster response (twice a month). PRODES uses Landsat TM and Brazilian-Chinese CBERS data, while DETER is fed by the MODIS sensors on board NASA's Aqua and Terra satellites. The data from both programs have been used by IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) and the Brazilian Federal Police to detect deforestation areas for operational purposes and law enforcement. However, the use of orbital optical sensors to detect deforestation in the tropical rainforest on the Amazon region is limited by the presence of clouds. Some areas remain covered for more than a year. This problem affects critically affects the time spend by the authorities mentioned above to react against the ongoing deforestation processes.

1.2 Proposed innovation

Past research has pointed out that data from SAR satellite sensors can be used to detect land cover changes in tropical forests. The Advanced Land Observing Satellite was launched in 2006, and from August 2007 its data became available to

IBAMA through the JAXA's ALOS Kyoto and Carbon Initiative project (K&C). The ScanSAR-ALOS is one of the products available under the K&C. With L band and HH polarization, it is suitable for vegetation analysis.

1.3 Study Site

The study area is defined by a rectangle (180km by 200km) centrally located in the state of Pará, Brazil, centroid with coordinates of 52° 47' 44" W and 6° 34' 03" S (**fig. 1**). It corresponds to an area of forest that has been facing a growing pressure of deforestation, with a good amount of recent deforested areas detected by DETER. The area was selected to be used as pilot area to test new methodologies on real-time deforestation monitoring.

Figure 1. Study site location in the Pará State, in the Brazilian Amazon Region.

1.4 The previous studies

Seasat was launched on 1978, and was the first Earth-orbiting satellite that had the spaceborne synthetic aperture radar (SAR), L-band, on board. The use of L-band orbital SAR images for vegetation analysis starts with SeaSat data, developing to the

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SIR-A,B and C data, followed by JERS-1 and recently with ALOS PALSAR data.

The L-band SAR images have been related with the canopies and have been related with biomass estimation and structure modeling. Luckman & al. (1998) developed a semiempirical model for the retrieval of above-ground biomass density on the tropical forests. Several papers were developed on this matter to understand this relationship. Neeffa & al. (2003) developed a model for the tropical forest stand structure using SAR data.

Sgrenzaroli & al. (2004) have shown that on the published remote sensing literature, there are several Amazon forest-mapping experiments actually deal with single SAR satellite images (i.e. JERS or European Remote Sensing - ERS), with focus on local-scale mapping. In this category, approaches based on visual inspection or automatic classification were investigated.

Saatchi & al. (1997) have studied the radar characteristics of the training sites on the State of Rondônia for land cover-type classes identification using L-band SIR-C data.

More recently, Almeida-Filho & al. (2005) evaluated the potential use of orbital L-Band SAR images of JERS-1, to test a multitemporal monitoring methodology. They found that for the initial deforestation process the proposed methodology is not able to unequivocally detect areas in initial phase of deforestation, and the unambiguous detection of deforested areas is only possible if the entire clearing process has already been concluded. They also mentioned that for an operational program to monitor deforestation, based on SAR data, it is very important to have a properly geo-referenced multi-temporal database to integrate different sources of data.

1.5   The problem

The use of orbital optical sensors to detect deforestation in the tropical rainforest is usually delayed due to presence of clouds. The age of a certain deforested area is defined by the period that starts when original forest was last observed and ends when deforestation was first observed with satellite images. Recent deforested areas are considered priority for law enforcement agents because they can indicate the ongoing deforestation processes. DETER's data provides deforestation polygons with an age that can vary from 15 days up to more than a year long (**fig. 2**). By the beginning of the dry season most of the deforested areas detected by DETER are old (more than 90 days) due to a long period without clear images. ALOS-ScanSAR can be used to identify recent deforested areas and to reduce the interval between two observations.
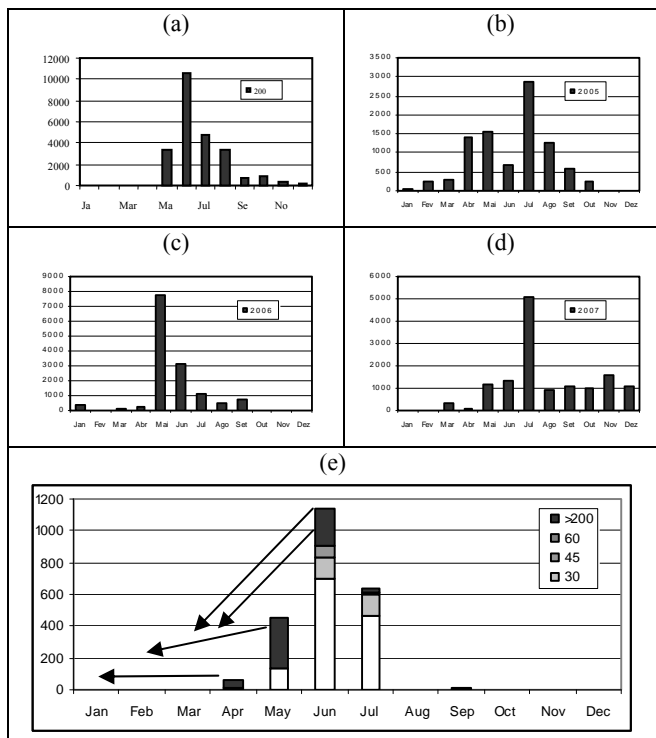
Figure 2. Monthly distribution of DETER deforestation detection in area (km^2). (a) 2004, (b) 2005, (c) 2006, (d) 2007, and (e) 2007 with the proportion of the each age per month in the beginning of the dry season.

2.   METHODS

2.1   ALOS and Optical images

ALOS strip of 2730km of length by 380km of swath, on wide bean mode 1 of ScanSAR images, with 100 per 100 meters resolution and HH polarization, of august 23rd, 2007. In order to validate the ALOS detection Landsat-TM images path 226 row 64 and 65 of September 2^{sd}, 2007 and path 225 row 64 and 65 of September 27th, 2007. CBERS images path 164 row 106 and 107 of September 11th, 2006 were used to verify the forest condition one year before the ALOS image acquisition. Images were registered using orthorectified images from Geocover Landsat Facilities project (GLCF orthorectified data).

2.2   Data Pre-processing

This study was conducted to test operational capability of ScanSAR images as complementary resource to the optical sensors already used in Brazil. First, an analysis was carried out in order to understand how deforested areas would show up on PALSAR sensor imagery. Than the ScanSAR strip mode image was geo-rectified and subset. DN image values were converted to the normalized radar cross section (σ^o), in dB, with a calibration factor of -83 dB.

2.3   Image processing

The ancillary deforestation areas previously detected by PRODES were masked to eliminate old deforestation areas. An analysis was done using all DETER data sets of the year 2007. The mean sigma value was extracted for all sets of DETER deforestation detections along the year 2007 and also for the rain forest. A Lee-sigma speckle reduction filter was applied to the ScanSAR image. This image was then classified using the

mean sigma value of the recent deforested areas as threshold to identify other deforested areas not detected by DETER.
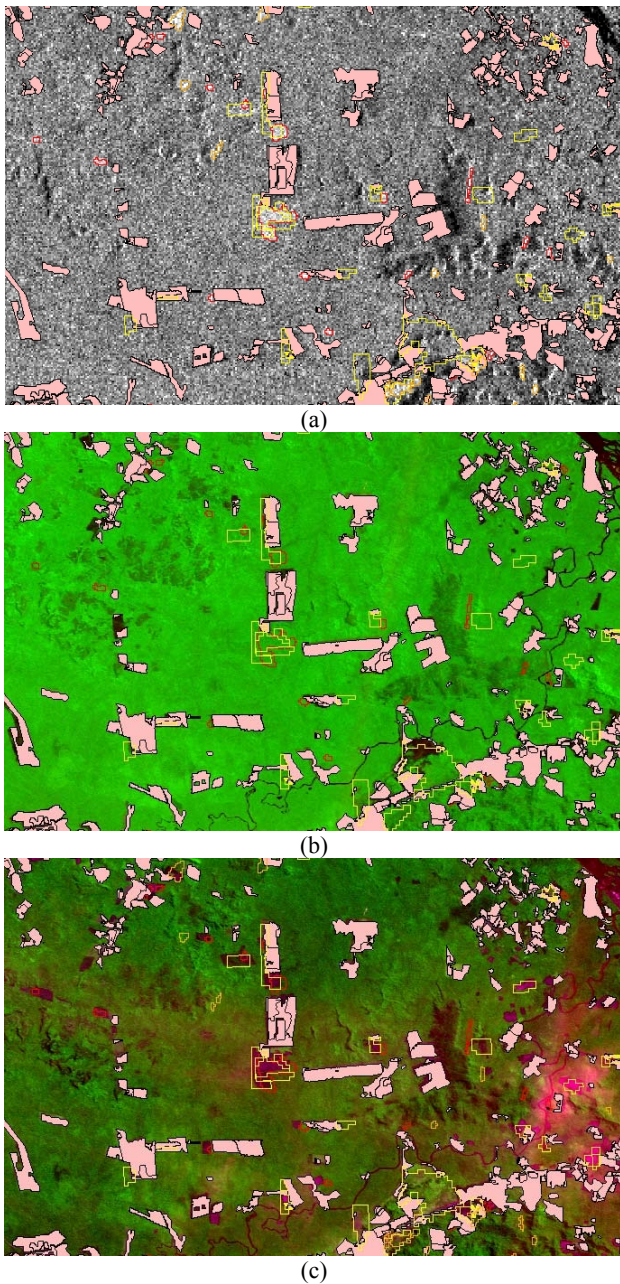

(a)

(b)

(c)

Figure 3. The yellow lines are the DETER detection polygons, the red lines are de ALOS detection polygons while the pink areas correspond the PRODES polygons. **(a)** ALOS ScanSAR image used with the defined threshold value and the to identify the possible recent deforestation, **(b)** CBERS Image from 2006 before to characterize the situation before ALOS image aqusition, **(c)** Landsat image after ALOS image acquisition.

An illuminated topographic image based on the position of the PALSAR sensor was generated from the SRTM data. The simulated image was used to exclude the classified areas that could present relief related response on the ScanSAR image.

3. RESULTS

Using the DETER polygons to extract average values inside these areas, was possible to recognize that most of older deforestations in the same year were low values compared with the very recent detections. The **figure 4** shows the average sigma values obtained for old deforestations (may be crops or pasture) compared with one year old deforested areas detected by DETER system using Terra-MODIS images and the signal obtained for primary forest.

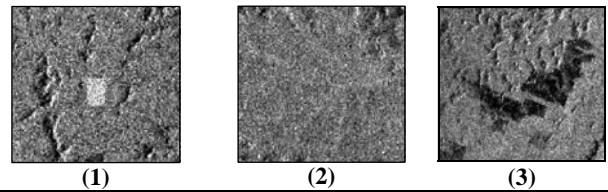| Class	Area	Min	Max	Mean	Std
DETER Recent (1)	2279	-12,330	4,204	-4,992	1,893
Forest PRODES (2)	132020769	-15,520	0,178	-7,254	1,818
Deforest PRODES (3)	162780000	-20,374	0,899	-11,020	2,505

| (1) | (2) | (3) |

Figure 4. Comparison between Very recent deforestation from DETER of the year 2007, Deforestation detected with PRODES system from 1997 to 2006 in average and the remnant primary forest identified by PRODES database.

The results showed that areas corresponding to old deforestation are related to low dB values, while recently deforested areas are related to high dB values. The mean σ^o value for recent deforested areas was -5.315dB and the mean σ^o value for preserved native forests was - 7.569dB.

Based on the threshold value classified ALOS image, 1476 polygons were generated. Using the arbitrary criteria that more than 10 degrees slope can be affected with an increased brightness, 1239 polygons on slope areas were eliminated. From the resultant 237 polygons, 133 were confirmed to be over the relief but were not eliminated because they were geographically displaced, one was a false detection, and 99 were confirmed deforestations. From the 99 deforested polygons, 19 were coincident with PRODES from the year 1997 to 2006 and 55 polygons with PRODES 2007 (finished on august 2007), 4 were on areas of non forest (neither considered by PRODES nor DETER) and 17 are new detections of ALOS, not detected by any other optical system.

4. DISCUSSION

The mean σ^o value for recent deforested areas, for preserved native forests and old deforested areas are similar to those found by other authors.

Covarage Type	1	2	3	4
Primary Forest	-7,254	-7.71dB	-9.71	-8.3 to 7.1
Recent deforestation	-4,992	----	-5.75	----
Old deforestation (may be crop or pasture)	-11,020	-1.11dB	- 14.45	-11.9 to -10.7

Table 1 – Comparison between the sigma values obtained from different studies: (1) present study, (2) Sgrenzaroli & al., 2004, (3) Saatchi & al., 1997 and (4) Luckman & al., 1998.

Almeida-Filho & al. (2005) notice the importance of high quality georegistration on the several databases in order to implement an operational monitoring system. In this study the georegistration was a very limiting factor and was solved by using the recent implementation of the geocoded methodology.

5. CONCLUSIONS

The executed methodology, using a threshold to classify new deforested areas, has a good potential to be the base of a semiautomatic detection system for operational purposes, using ScanSAR images. This system has potential to produce data that could complement the information already available from optical sensor satellites (CBERS-CCD, Landsat-TM and Terra-MODIS images). The resulted monitoring system, combining optical and SAR data, would decrease the average age of the deforested areas. As a result, the response time related to law enforcement activities to combat illegal logging would decrease.

Two points need to be stressed here. One is the new detections of ALOS images which were not detected by any other optical systems. These detections are probably related to very recent deforestations that may have occurred some days before ALOS image acquisition. The second point is the number of ALOS detection coincident with PRODES 2007, these detections can be used to the enforcement law agents, because these polygons where not detected by DETER until the end of the year when the mask were changed to the PRODES 2007 database.

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