ALOS PALSAR ScanSAR in support of the Brazilian Forest Monitoring Program

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***Abstract*— This paper presents an assessment of the use of the ALOS PALSAR, Kyoto and Carbon Initiative and ScanSAR data for the Brazilian Forest Monitoring Program. Using deforestation polygons mapped by INPE's DETER project, PALSAR ScanSAR multi-temporal images were analyzed for the detection of deforestation patterns. The obtained result shows that approximately 50% of the polygons could be detected by PALSAR ScanSAR images for areas larger than two square kilometers. It is notable that these deforestation patterns were detectable before the DETER Alerts. A multi-temporal approach is proposed to efficiently process the ScanSAR data, enhance their quality, and generate, in an automated way, recent deforestation. It consists of a radiometric re-calibration of the slant range gamma nought input data, a multi-temporal co-registration and speckle filtering, a terrain geocoding, a multi-temporal anisotropic non-linear diffusion filtering, and finally, an automated classification compatible with the PRODES clear mapping. Considering the importance and extent of the Amazon forest and its cloud cover conditions, the PALSAR ScanSAR-based product is now under evaluation for integration within the Forest Monitoring Program. Furthermore, assimilation of the proposed product into the operation of the DETER project is a first step – within the INPE's Forest Monitoring Program – toward the integration of additional SAR (Synthetic Aperture Radar) products based on the forthcoming planned Brazilian sensors, such as MAPSAR and CBERS-7.**

***Index Terms*—ALOS PALSAR, ScanSAR, deforestation, K&C Initiative, DETER, forest monitoring, Amazon.**

I. INTRODUCTION

A. Deforestation and SAR data over Brazilian Amazon

Early deforestation stages by slash-and-burn practices have been identified from L-band JERS images as patterns that are distinct from those of the original forest cover in the Brazilian Amazon [1]. Airborne L-Band data have also been demonstrated to be highly sensitive to radiometric differences between recent deforestation and the primary forest [2].

Polarimetric radar data acquired through a MAPSAR simulation also showed the capability to detect recent deforestation over Tapajós National Forest (Pará), in the Brazilian Amazon [3]. Among the polarimetric data, HH-HV proved to be the most adequate polarization combination for land cover mapping. It is capable of discriminating between primary forest, secondary forest, bare soil, agriculture and degraded forest [4]. Preliminary investigations using PALSAR images with only HH polarization over Amazonia showed distinct responses from slash-and-burn practices and different degradation stages of the forest [5].

Comparisons between the optical and radar images suggested that SAR L-band images are an important and complementary information source for land cover change mapping, especially over frequently clouded areas as is most of Amazon region [6].

This paper describes a project developed within the Kyoto & Carbon (K&C) Initiative [7], which assesses the use of ALOS PALSAR K&C images for the Brazilian Forest Monitoring Program from INPE. Within this paper, we discuss the utility of PALSAR ScanSAR imagery as an additional source of information for the DETER system and to publish recent deforestation areas (warnings) while overcoming the frequent cloud cover over the Amazonia region. First, we verify whether the deforestation warnings from the DETER system can be identified from PALSAR ScanSAR imagery. Second, we evaluate the contribution of a single ScanSAR scene for the DETER system considering the time and area for deforestation detection. Finally, we presented a methodological approach developed to identify recent deforestation based on the use of K&C PALSAR ScanSAR images and a multi-temporal approach.

B. ALOS Imagery for forest monitoring in Brazil

The Brazilian Institute for Space Research (INPE) conducts the Amazon Deforestation Monitoring Program. This program is comprised of a set of remote sensing based systems to monitor the state of Amazonian forest cover. The Real-Time Deforestation Detection System [8] identifies and maps recently deforested areas in the Brazilian Amazon forests every fifteen days to support law enforcement for deforestation control. DETER is based on TERRA/MODIS and CBERS-2B/WFI images, benefitting from their high revisiting capability. With the spatial resolution of both sensors limited to 250 meters, DETER maps new deforestation areas of at least 25 ha. In DETER, all deforestation identified in an image that has not been previously detected by the Legal

Amazon Deforestation Monitoring Project [9] is considered new deforestation, regardless of chronological placement. The PRODES map, containing deforestation from prior years, together with non-forest areas (such as savannah, water surfaces and rocky outcrops) is used to mask out old deforestations. New deforestations are detected and outlined by visual interpretation of the MODIS image.

For every interval of 15 days, the best set of images was selected to attain maximum cloud-free data. DETER produced a digital map with all of the new deforestation observed during this period. These digital maps contained Alert polygons and the tables describing them were sent to IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) within 15 days after the image acquisition period. IBAMA is responsible for law enforcement and deforestation control at the Federal level. A cloud cover map was also provided to inform the area that was effectively monitored. The maps for the two halves of each month were integrated and, together with the cloud cover maps and images for the period, placed on the Internet (http://www.obt.inpe.br/DETER/) for consultation, where they remain available for download.

For monthly DETER data, a technical report assessing DETER information and results was also published on the Internet. Based on cloud-free and high spatial resolution images (20 – 30m), a sample of DETER Alert polygons was validated. Multi-temporal and visual analysis classified DETER Alert polygons as light forest degradation, moderate forest degradation, intense forest degradation, clear cut and non-confirmed deforestation. The validation results provided basic information about the types of deforestation mapped by DETER and data accuracy, while also considering the polygon area information. From May to August, 2008, an average of 91% of DETER Alert polygons were confirmed as deforestation [10]. Data from field observation was also periodically obtained to improve DETER methodology and data evaluation [11]. In September 2008, an INPE team went for a field expedition along the southwest of Para. With IBAMA collaboration, DETER Alert polygons were checked from a helicopter flight.

This validation of DETER Alert polygons using optical remote sensing imagery is strongly limited by the cloud cover over the Amazon region. A preliminary but essential application for ALOS PALSAR K&C images for deforestation monitoring is their assimilation into DETER validation procedures as well as the identification of Alert polygons over the areas with cloud cover. It was not expected that PALSAR imagery would provide information about different deforestation intensities as they are usually detected by optical images and a multi-temporal approach. However, radar backscatter data did provide information about general forest cover conditions:

- Deforested areas older than one year (PRODES mapping) presented dark patterns (between –14 and –15 dB) at L-band SAR.

- Areas of less than one year of deforestation (PRODES mapping) detected by L-band SAR are represented by lighter areas (-13 dB approximately);
- Very recent deforestation mapped by the DETER Program and discernible by L-band SAR are represented by lighter (between –12 and -11dB) polygons.

II. Description of the project

A. Relevance to the K&C Initiative

The use of PALSAR imagery operationally with the DETER system, as an improvement of the forest monitoring system, is in accordance with the Conservation thematic driver outlined in the K&C Science Plan [12]. To effectively monitor deforestation, especially over frequently cloud covered areas, PALSAR information will be very helpful in defining policies and plans of action, either for carbon emission reduction or for conservation strategies.

B. Work approach

This project was conducted in two parts. Initially, we assessed PALSAR K&C ScanSAR imagery for deforestation detection taking DETER Alert data as a reference. Second, based on the outcome of the assessment, a methodology aiming at the automated detection of deforestation areas was developed and validated. The final goal is to include the proposed processing chain and related product on an operational basis in the Forest Monitoring Program.

Although the PALSAR Fine Mode data provided an excellent spatial resolution for detailed analysis, the ScanSAR data were preferred. This is because these strip data can cover large extensions (several 1,000 km in flight direction, 350 km range swath) with a high temporal repetition frequency (6 acquisitions per year are available), hence enabling systematic monitoring over the whole Amazon forest (approximately 4 million km^2 of forest). For use of PALSAR Fine Beam Mode, refer to [13].

III. ALOS PALSAR ScanSAR and Deforestation detection

A. ALOS ScanSAR and recent deforestation patterns - satellite and ground data

Deforestation processes vary according to regional differences in Brazilian Amazonia. The state of Pará, our study site, is generally orientated to pasture as its final use. However, selective logging and understory degradation can also occur as a progressive forest degradation process before the complete removal of trees (clear-cutting). Deforested areas can also be used to provide subsistence agriculture before they are completely converted to pasture (Figure 1). During these successive steps, the land can be abandoned and, according to the local dynamic, regrowth can be installed. Fire is frequently used as technique to prepare the soil before cultivation and for pasture renewal.

Figure 1. General deforestation process observed for the state of Pará.

Deforestation detection in the SAR L-band also has a temporal dynamic that must be considered to correctly interpret the radar backscatter. Recent deforestation shows a brighter backscattering pattern (about -11 dB) than the forest cover background (less than -12 dB). This pattern is associated with the forest degradation process, in which the highest trees are removed and the trunks that are lying on the soil produce a strong radar backscatter (in premise, double bounce). The moisture content of the vegetation (leaves and trunks) is also a contributing factor. For the detection and identification of this deforestation, the use of PALSAR ScanSAR HH imagery has been shown to be appropriate. As these deforested areas will progressively become drier, and the trunks removed, the backscatter will be lower (around -13 dB). As it progressively becomes darker, deforested areas are no longer distinguished from the forest background at HH polarization. This change in the backscattering pattern occurs within approximately 5 months, depending on the rainy season and the consequent soil moisture variation. One year later, these areas are used for pasture or agriculture. The backscatter then becomes very dark (around -15 dB) and clearly identifiable in the PALSAR HH data.

In accordance with the methodology of this project, we first managed to develop a tool to store and recover every image from the K&C project. An automatic procedure was implemented to regularly access JAXA ftp sites and organize the available ALOS PALSAR K&C images in a database. Using a web portal, credentialed users can consult the downloaded images by date, polarization or central geographical coordinate (http://www.dpi.inpe.br/sima/bancos). The image swath can be visualized and the selected images can be ordered from the database manager. As soon as JAXA authorizes, the portal will allow the Brazilian scientific community to freely access this PALSAR image database

For this analysis, a PALSAR ScanSAR image from August 30, 2008 (WB1, HH polarization, slant range KC_003-21406N09S21WB1SLT1, gamma nought) was terrain geocoded to a grid size of 100 m using the nominal parameters exclusively. The georeferenced gamma nought image was subsequently integrated into the deforestation data sources using geographical information systems developed by INPE (SPRING [14] and TERRAVIEW [15]). The SAR data processing was carried out using SARscape [16].

Every clear-cut polygon was visually interpreted to identify differences in the radar backscatter between the forested and deforested areas. Typically, variations were detectable either as linear patterns with bright values (-12 dB) for recent cuts, or as dark patterns (-15 dB) representing older deforested areas.

The DETER Alert polygons from the May to August 2008 field check (September, 2008), located at the municipalities of Itaituba, Novo Progresso and Altamira (PA), were superposed to the PALSAR K&C image from August (Figure 2). All of the analyzed DETER polygons referred to clear-cut deforestation. This comprised areas that will likely be converted to pasture, as exemplified in Figure 3 (yellow square outlined at Figure 2).

Figure 2. Study site. Helicopter flight route over (a) Landsat-TM color composition and (b) ALOS ScanSAR image (WB1-HH–083008). Municipalities of Altamira, Novo Progresso and Itaituba (PA), Brazil.

Figure 3. Example of DETER clear-cut Alert polygons over ALOS ScanSAR image (WBS-HH–083008). DETER polygons are from June (light blue), July (dark blue) and August (black) close to Curuá River (Altamira-PA).

Considering only clear-cut DETER Alert polygons verified in the fieldwork, (a total of 67 polygons from May to August, 2008), the PALSAR ScanSAR image could detect only 55.22% of the clear-cut polygons (Table 1).

Table 1 – ALOS PALSAR ScanSAR image assessment for DETER clear-cut polygons verified during the fieldwork.

Two factors could contribute to this result:

- The radiometry of PALSAR ScanSAR image (gamma nought) was not properly corrected. There was a significant difference in image illumination (near to far range) and within the image, resulting in a difficult interpretation.
- The DETER clear-cut polygons located in flat terrains were easier to detect than in those in sloped areas, resulting in strong foreshortening and, hence, reduced geometric resolution.

It was observed that DETER Alert polygons detected by the PALSAR ScanSAR image (Table 2) had an average of 4.33 km^2, which is in contrast to the polygons not detected in the PALSAR image that presented average areas of 2.65 km^2.

A second analysis was performed observing only DETER Alert Polygons for September 2008 over the ALOS PALSAR ScanSAR image from October (10-15-2008) with the same methodological procedure. This analysis simulated the use of PALSAR ScanSAR in an operational basis, i.e., a single PALSAR image and the fortnight DETER Alert polygons.

Table 2 – ALOS PALSAR ScanSAR image assessment for DETER clear-cut polygons verified during the fieldwork.

Observing DETER Alert Polygons for September 2008 over the ALOS PALSAR image from October (10-15-2008), only 76 polygons out of 565 were placed over the PALSAR ScanSAR scene. Even with DETER polygons smaller than registered previously, 45% of the polygons were identified over the PALSAR ScanSAR image (Table 3). Most of the deforestation polygons presented dark values (-13 dB) in the PALSAR image, suggesting older clear-cut areas.

Table 3 – ALOS-PALSAR ScanSAR image (October) assessment for DETER clear-cut Alert polygons registered for September 2008.

The temporal deforestation-backscattering dynamic explains the capability of PALSAR ScanSAR imagery in detecting deforested areas earlier than the DETER System, which is restricted by cloud cover and bare soil reflectance to map deforestation. From the analysis of deforestation evidence from the PALSAR ScanSAR images (Table 4) for January, May, August, and October 2008 and April 2009, some DETER deforestation polygons were first evident from previous ScanSAR images, as observed in October in 2008. Additionally, deforestation is better identified in images from the dry season. April represents the end of rainy season, and 2009 was an exceptionally wet year, with the second highest flooding in the last 50 years for the Amazonia Basin. This explains the absence of deforestation evidence in April 2009.

Table 4 – – Evidence of deforestation in ALOS PALSAR ScanSAR images in relation to DETER clear-cut Alerts.

Such temporal variation - which is the result of roughness and moisture changes – for deforestation patterns in the Amazonia region will require further detailed analysis to better understand and quantify the interrelations between the deforestation process and radar backscattering.

When considering the results showing the potential of PALSAR ScanSAR data for early detection of deforestation, it is necessary to develop a methodology based on the exploitation of multi-temporal data for operational forest monitoring.

B. A multi-temporal approach to detect deforestation based on ALOS ScanSAR imagery

In determining whether PALSAR ScanSAR HH imagery can be used as a source information complementary to the DETER system, a multi-temporal approach was proposed to identify fortnight deforestation warnings. Prerequisite was that the methodology be robust, fast, reliable, and that the products can be straightforwardly integrated into the deforestation monitoring system.

Considering the deforestation hot spot region in the state of Pará in the municipality of Novo Progresso (Figure 4), the methodology was developed based on six ScanSAR images for the rainy and wet seasons of 2007 and 2008. The images are related to the same path (RSP406), descending mode (WB1, K&C format), slant range, and HH polarization from the following dates: 05-

28-2007, 07-13-2007, 08-28-2007, 01-13-2008, 05-30-2008, and 08-30-2008. The deforestation results were compared to the deforestation mapping from PRODES 2007 and 2008.

Figure 4. Study area. Municipality of Novo Progresso (red dot) and rainy season variation in the state of Pará (Source: [17])

Algorithms specially developed to work with the PALSAR K&C format in the SARscape framework enabled radar image pre-processing. The general workflow proposed is summarized in Figure 5.

Figure 5. Methodological procedure proposed to classify deforestation based on PALSAR ScanSAR multi-temporal series

The peculiarity of the K&C format [7] is that the SAR data are in slant range projection, are multi-looked, and are provided as gamma nought. Hence, radiometric effects due to the antenna gain pattern, range spread loss, scattering, and incidence angle dependency are to be corrected. Two major scene-dependent problems from these data types should be noted: 1) The slant range data, probably due to time synchronization inaccuracy, do not allow for nominal terrain geocoding. As a result, for each image one Ground Control Point is requested to accurately georeference the images. 2) The observed gamma nought often shows radiometric variations (in the order of 1 to 2 dB), which prevents the identification of some changes. The most significant variations are visible in the near to far range changes, residual antenna gain patterns and scattering area effects.

It was anticipated that a rigorous correction (i.e., application of the radar equation) of these data at this processing level is unthinkable because no information from the processor is available. In facing this situation, the ScanSAR gamma nought data, after import, were radiometrically corrected by applying an equalization of the gamma nought data. This was done by computing an average value for each range column. This was subsequently applied to the whole image as a normalization factor. In this way, the mentioned scene-dependent radiometric variations were significantly reduced.

Concerning geometric (azimuth shifts) scene dependence, the multi-temporal data are coregistered in the slant range geometry. In this way, only one Ground Control Point is requested to accurately geocode all of the temporal data set for terrain.

Coregistration simply superimposes onto the slant geometry two or more SAR images having the same acquisition geometry. This procedure brings the advantage of perfect matching between PALSAR images. This is required to enable speckle filtering based on time-series to explore the space-varying temporal correlation of speckle between the images, which reduces the system’s inherent multiplicative noise.

The De Grandi multi-temporal speckle filter, an optimum weighting filter used to balance differences in reflectivity between images at different times [18], was applied over the PALSAR ScanSAR images from 2007 and 2008. A correction for the illumination from the antenna pattern was then applied over each image, and the power values were converted to gamma nought (γ^0) in linear units. After this procedure, the radiometric correction of the multi-temporal image series was completed.

During the geocoding procedure, the geometry of the scenes were corrected using a Digital Elevation Model (DTM), from SRTM data (90 m), as input to convert the positions of the backscatter elements into ground-range image coordinates. The images were re-sampled to 100 m of spatial resolution and were compatible with Geographical Projection, datum WGS84.

To enhance discrimination between classes, the Multi-temporal Anisotropic Non-Linear Diffusion Filter (ANDF) was applied. This filter takes advantage of the redundant information available when using multi-temporal images by applying a hybrid multi-temporal anisotropic diffusion scheme [19].

Based on the analysis performed by combining PALSAR ScanSAR data with DETER polygons, a rule-based classification approach based on the multi-temporal corrected gamma nought was proposed. The obtained classification of the deforested areas was subsequently segmented and the vectors exported into INPE'S Geographical Information System. This enabled comparison with the official deforestation mapping from PRODES.

Results from the Multi-temporal approach to classify deforestation based on ALOS PALSAR ScanSAR

The proposed methodology, as illustrated in Figure 6, strongly reduces the crucial radiometric variations and it solves the geometric problems. The color composite of August and May 2008 clearly shows the difference between the provided γ^o and the corrected γ^o. Furthermore, the multi-temporal speckle filtering combined with the ANDF considerably improved the discrimination capabilities of the targeted land covers, hence facilitating identification of the deforestation limits (Figure 7).

Figure 6. ALOS PALSAR ScanSAR (080830(R), 080530 (G and B)) coregistered (a), and after radiometric correction (b).

Deforestation polygons obtained from PALSAR ScanSAR imagery (100 m) were compatible in shape to deforestation polygons mapped from the PRODES imagery database (30 m) (Figures 8 and 9). The smallest deforestation polygon detected by PALSAR ScanSAR imagery present area equal to 0.8 km^2.

As only three PALSAR ScanSAR scenes were used to identify deforestation for annual PRODES mapping, only part of the total deforestation polygons for the reference year were detected. A longer PALSAR ScanSAR time-series would probably detect a similar number of deforestation polygons.

During the rainy season, new deforestation areas presented backscatter responses similar to water bodies under the canopy of trees. The inclusion in the classifier of geometrical descriptors could easily solve this problem; in fact, deforestation pattern are typically rectangular with linear boundaries while flooded areas follow the rivers' dendritic patterns.

A problem that it is still under analysis (in order to enable an automated classification) is the discrimination between soil moisture and local rainfall, as observed in the black circle depicted in Figure 9a. In these cases, the backscattering shows significant radiometric variations (from –10 to –14 dB). The result is that recent deforestation is very hard to distinguish from the forest background.

Topographic effects have still not been completely removed. The resulting features are responsible for most of deforestation polygons detected from PALSAR ScanSAR imagery, which are absent from the PRODES deforestation mapping (Figures 8b and 9b). The only way to fully compensate for these effects is to process the ScanSAR data from the SLC format and rigorously apply the radar equation. Starting from the gamma nought format, these effects are hard to be reduced.

Figure 7. ALOS PALSAR ScanSAR 2007-08-28 (R), 2007-05-30 (G), 2008-01-13 (B) after geometric correction (a); ANDF multi-temporal filtering (b).

Figure 8. Deforestation polygons from ALOS PALSAR ScanSAR 2007 classification (yellow vectors) over (a) color composition 2007-08-30 (R), 2007-07-13 (G), 2007-05-28; and (b) PRODES 2008 deforestation mapping

Figure 9. Deforestation polygons from the ALOS PALSAR ScanSAR 2008 classification over (a) color composition 2008-08-30 (R), 2007-05-30 (G), 2007-01-13 (red vectors); and (b) PRODES 2008 deforestation mapping (white vectors).

IV. Final Comments

From the results obtained over our test sites, PALSAR ScanSAR images can be considered a useful source of data for the Brazilin Forest monitoring program. From ScanSAR data, it is possible to identify approximately 50% of the deforestation detected by DETER for areas preferably larger than two square kilometers. Eventually, deforested areas will be detected even before DETER Alerts.

With the proposed methodology, data processing on a multi-temporal basis can be performed in an automated way. As the multi-temporal series has the same geometry and compatible radiometry, it can be used to detect and also monitor deforested areas on a regular basis. Having a new ScanSAR scene, it will be introduced into the workflow and compose the multi-temporal series. This will result in deforestation polygons compatible with DETER and PRODES mapping. To operationally use the method proposed at this stage still requires human interaction at the classification level. This is because the still existing topographic and moisture effects of radar backscattering are misinterpreted as deforestation polygons. The first problem could be overcome by starting the processing from Single Look Data and applying the rigorous radar equation to work instead with the K&C format (γ^o) while properly considering azimuth time synchronization (hence omitting the use of a GCP for the whole temporal data set). The second problem could be solved by taking into account two multi-temporal signatures for different cases.

The proposed methodology can also be improved using, for instance, the results from a previous classification as input for the following ScanSAR scene, or fusing PALSAR ScanSAR data with other sensors such as ENVISAT ASAR Wide Swath data.

Intense imagery monitoring over a study site supported by fieldwork would better describe deforestation and backscattering relationships.

The ALOS K&C Initiative gave us the opportunity to consider the use of radar data to overcome the cloud cover problem in the Brazilian forest monitoring system. Radar data availability on a regular basis enables the development of an operational procedure to use the L-Band for deforestation detection.

The results obtained so far indicate that PALSAR ScanSAR imagery has the potential to detect only part of the deforestation polygons that are normally published as deforestation alerts. However, as deforestation detection has to be operational and expedited, an uncomplicated approach is needed based on ScanSAR – HH polarization data and the multi-temporal and automatic classification that is under final development.

Another benefit from being part of the ALOS K&C Initiative and conducting this project is the construction of a radar culture, not only at the scientific level, but also at an operational basis. This will have implications for public awareness about the technological capability of remotely sensed monitoring of the deforestation process in Brazil. This is especially important considering that the Brazilian Spatial Program is planning to develop radar sensors onboard Brazilian satellites in the next decade.

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FIGURES

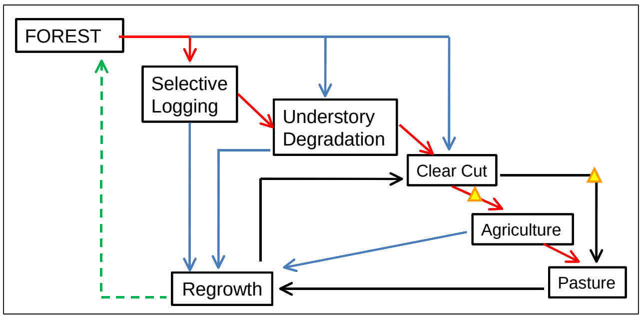

Figure 1. General deforestation process observed for the state of Pará.

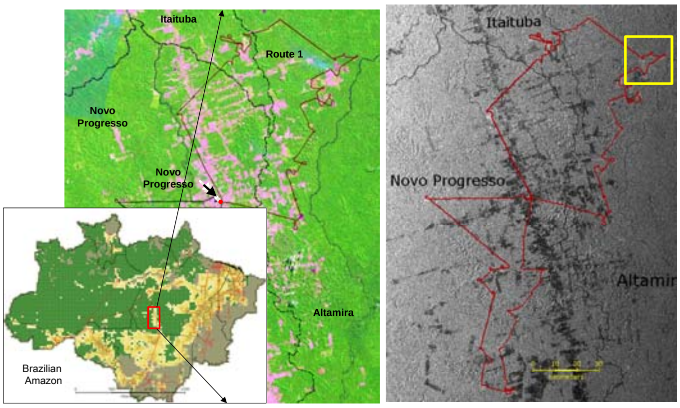

Figure 2. Study site. Helicopter flight route over (a) Landsat-TM color composition, and (b) ALOS ScanSAR image (WB1-HH–083008). Municipalities of Altamira, Novo Progresso and Itaituba (PA), Brazil.

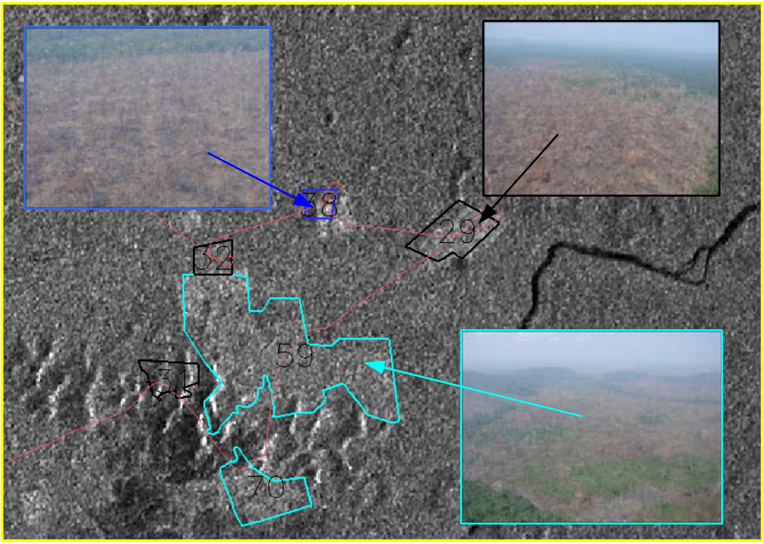

Figure 3. Example of DETER clear-cut Alert polygons over ALOS ScanSAR image (WBS-HH–083008). DETER polygons are from June (light blue), July (dark blue) and August (black) close to Curuá River (Altamira-PA).

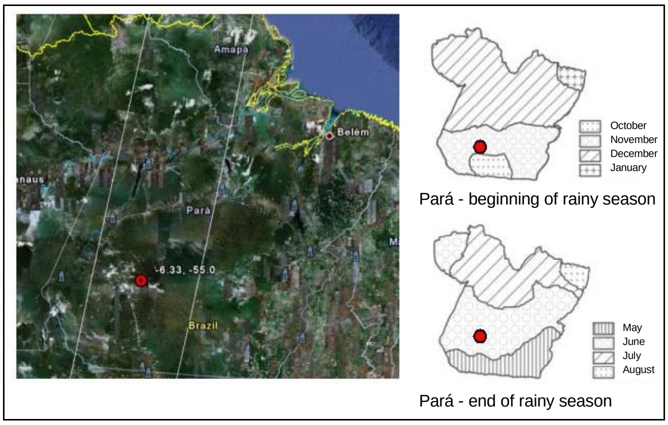

Figure 4. Study area. Municipality of Novo Progresso (red dot) and rainy season variation in the state of Pará (Source: [17])

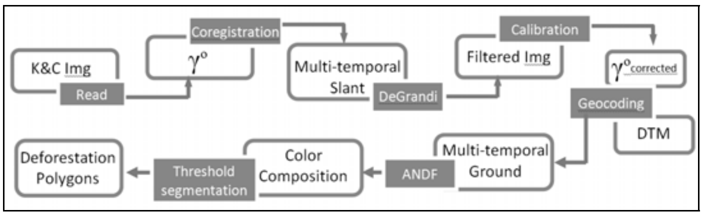

Figure 5. Methodological procedure proposed to classify deforestation based on PALSAR ScanSAR multi-temporal series

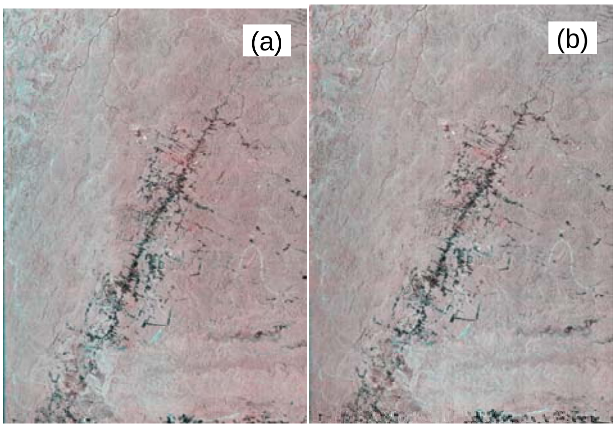

Figure 6. ALOS PALSAR ScanSAR (080830(R), 080530 (G and B)) coregistered (a), and after radiometric correction (b).

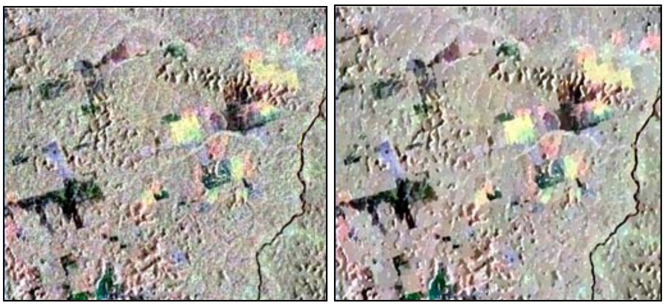

Figure 7. ALOS PALSAR ScanSAR 2007-08-28 (R), 2007-05-30 (G), 2008-01-13 (B) after geometric correction (a); ANDF multi-temporal filtering (b).

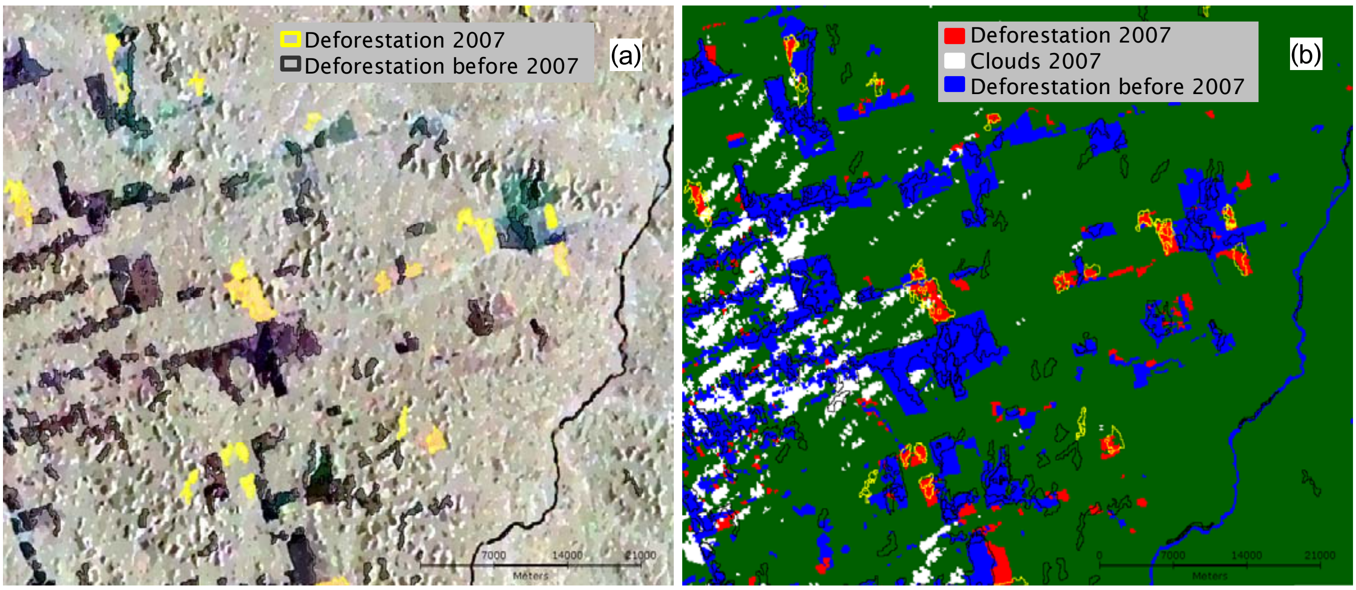

Figure 8. Deforestation polygons from ALOS PALSAR ScanSAR 2007 classification (yellow vectors) over (a) color composition 2007-08-30 (R), 2007-07-13 (G), 2007-05-28; and (b) PRODES 2008 deforestation mapping

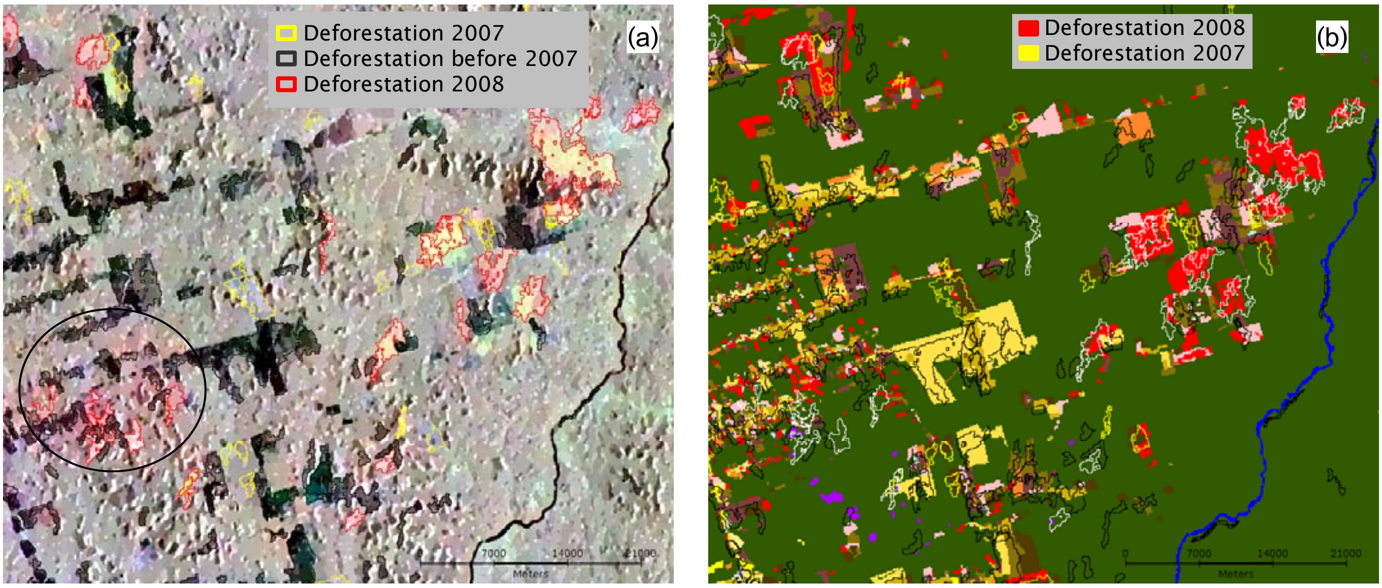

Figure 9. Deforestation polygons from ALOS PALSAR ScanSAR 2008 classification over (a) color composition 2008-08-30 (R), 2007-05-30 (G), 2007-01-13 (red vectors); and (b) PRODES 2008 deforestation mapping (white vectors).

TABLES

Table 1 – ALOS PALSAR ScanSAR image assessment for DETER clear-cut polygons verified during the fieldwork.

	DETER Clear-cut polygons	PALSAR August	%
May	12	6	50.00
June	17	7	41.18
July	14	10	71.43
August	24	14	58.33
Total	67	37	55.22

Table 2 – ALOS PALSAR ScanSAR image assessment for DETER clear-cut polygons verified during the fieldwork.

	DETER polygons average area (km^2)	
	Detected	**Not detected**
May	7.00	3.86
June	5.51	3.21
July	2.46	1.68
August	2.35	1.83
Average	4.33	2.65

Table 3 – ALOS PALSAR ScanSAR image (October) assessment for DETER clear-cut Alert polygons registered for September 2008.

ALOS (10-15-2008)	DETER Polygons (Sept-2008)	%	Area (km^2)
Detected	34	44.74	0.92
Undetected	42	55.26	0.75
Total	76		

Table 4 – Evidence of deforestation in ALOS PALSAR ScanSAR images in relation to DETER clear-cut Alerts.

		PALSAR ScanSAR 2008/2009				
	DETER	**Jan**	**May**	**Aug**	**Oct**	**Apr**
Def 2007		11		3	1	
May	9		6	5	2	
Jun	22	1	3	7	1	
Jul	18	1		4	2	
Aug	29		1	9	5	
Sep	1				1	
Oct	68	2		8	6	1
Nov	6					
NA		1	2	1	1	
Total	**153**	**16**	**12**	**38**	**20**	**9**

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