Deforestation and indigenous settlements in western Roraima (Brazil)

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Abstract

Our research aimed at using ALOS images in order to assess the progress of deforestation near and in the land of the Yanomami Indians in Roraima (Brazil), and at detecting possible invasion of this protected territory. Use of SAR images for this purpose was due to the fact the Roraima is an area of high cloud cover, which makes more difficult the use of optical data.

Keywords: Brazil, Amazon, deforestation, indigenous settlements.

INTRODUCTION

Research background

Although it has decreased since 2004, deforestation remains high in the Brazilian Amazon region, with a conversion of forest areas to cropland and pastures of more than 12 000 km² each year (Le Tourneau, 2003). Detection and monitoring of this phenomenon has greatly improved since 2002 with the availability of new instruments (from MODIS to the high resolution C-BERS2), but also with a far greater accessibility of remote sensed data, today easily downloadable from a number of institutions.

However, many problems linked with this topic remain open. First, a number of regions in the Amazon see frequent cloud cover which makes them very difficult to work with optical data. Second, the region dimensions make it impossible to process all the required images in order to offer a complete assessment of the deforestation. Third, actual techniques focus on detecting the conversion from forest to cropland or pasture, but few techniques are available in order to study changes within the forest structure, for instance due to selective logging. Fourth, detection of small deforestation patches, many times linked with indigenous presence, is difficult with the available optical instruments. ALOS data could help bridge many of those gaps, offering high resolution and cloud-free vision.

Another focus that has emerged in the Brazilian Amazon is the importance of indigenous territories for the conservation of the forest (Le Tourneau, 2006). In facts, indigenous lands officially recognized total more than 1 050 000 km², or roughly about 23 % of the whole Brazilian Amazon area. Being almost completely preserved from deforestation, those territories will be at stake in the future when other forest area will have been depleted. Some of them, already in contact with deforestation fronts, already see invasions from loggers or farmers.

As an example of this topic, our research chose to focus on the western Roraima area. In this zone, the Yanomami Indian territory (which covers 96 500 km² of totally preserved Amazonian forest, see Le Tourneau, 2010), is in contact with the active deforestation front of Roraima's Mucajaí-Ajarani region (Albert and Le Tourneau, 2004). As a result of this contact, invasions are likely to occur, as well as redeployment of indigenous settlements.

Research objectives

The overall research objectives are to evaluate ALOS data utility for detecting automatically a number of objects linked with the monitoring of indigenous lands and possible invasions. Those object include deforestation plots (with a question of the minimum size they must have in order to be detected), roads, discrimination of cropland and pastures, but also indigenous gardens and settlements, in order to study the impact of possible invasion front on their dynamics.

Our objectives were to gather sample dataset on the area of study, to get familiar with ALOS data structure and to test visual interpretation and simple classification algorithm on a number of zones for which ground truth data were available due to fieldworks held from 2004 to 2006. Various ALOS data types were to be tested: fine beam single polarimetry, fine beam dual polarimetry and polarimetric mode. Comparison with other available data, especially CBERS-2 images) were also to be tested.

Sites of study

Two sites of study were elected for our project, due to ground truth data available and good local knowledge from the research team.

The first one is the Watorikɨ indigenous village. Although it is not situated exactly near the border of the Yanomami land, previous studies on this site using optical remote sensing (Albert and Le Tourneau, 2007) made it a very good area for evaluating the efficiency of ALOS data for detecting indigenous structures.

The second one is an area known as the “Ajarani” area, where the Yanomami territory is in contact with a number of colonization projects, some being about 30 years old and others open only recently.

A third site situated in a mountainous area was abandoned because of the deformation of images due to the hills. Therefore, the objective of detecting wildcat mining in this area was not achieved.

MAIN PART

1. Collected data

A number of images were acquired from JAXA, from INPE (Brazil) and from SPOTIMAGE (France):

ALOS DATA

- Watoriki area

- 1 PLR (HH/HV/VH/VV) image acquired 2006 08 26 (ID ALPSRP031293580), level 1.5
- 1 FBD (HH/HV) image acquired 2007 09 04 (ID ALPSRP085780010), level 1.5
- 1 FBS (HH) image acquired 2006 07 22 (ID ALPSRP026120010)

- Ajarani area

- 2 PLR (HH/HV/VH/VV) image acquired 2007 03 23 and 2007 05 25 (ID ALPSRP061710040 and ALPSRP070900030), level 1.5
- 2 FBS (HH) image acquired 2007 01 12 (ID ALPSRP051500020 and ALPSRP051500030) , level 1.5

CBERS-2 DATA

- Watoriki area

- Image CBERS-2 CCD path/row 177/098 acquired 2007 02 01

- Ajarani area

- Image CBERS-2 CCD path/row 175/98 acquired 2006 09 04

SPOT DATA

- Watoriki area

- Image…

2. Methodology of analysis

The acquired images were imported into ENVI software using the RAT routines [1], and analyzed visually, in comparison with optical data of the same areas. Tests were conducted on the possibility to detect the objects that we were interested in into the ALOS images. Several classical radar filters (Frost, Lee, Kuan) were tested in order to diminish the speckle and to improve the images readability.

Vector data already produced by our team or imported from external sources (such as INPE PRODES data,

[1] RAT is a package developed at the Berlin University of thechnology, see http://www.cv.tu-berlin.de/rat/

picturing deforestation) were then imported in order to test the accuracy of the georeferencing of the images.

Last, maximum likelihood classifications were applied on the polarimetric data and their result was vectorized and tested against the vector data.

3 Results

The georeferencing of 1.5 level images was tested as acceptable, but needing some work in order to correspond exactly with ground tested data. Linear displacement of about 500 meter in latitude and about 100 meters in longitude were necessary in order to place the images correctly.

The very high resolution of ALOS data (6,25 meter por pixel in fine beam mode) was thought to be an interesting solution for the detection and study of indigenous settlements, for those objects are in general of very small size.

But, as for now, results were not very successful. ALOS images appear not to show much sensibility in the fine beam mode towards indigenous garden plots or villages, as show the comparison between figure 1 and 2.

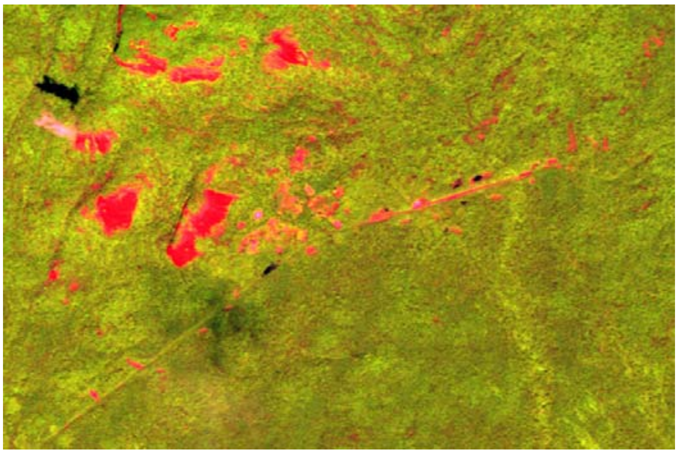

Figure 2. TheWatoriki area (SPOT-5 HRG image)

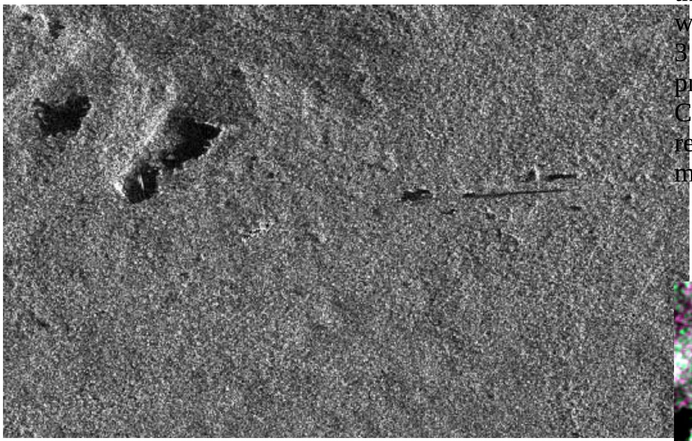

Figure 1. TheWatoriki area (PALSAR FBS)

As a matter of facts, if the Watorikɨ landing strip and the neighboring lakes can be identified in both images, the village and surrounding gardens do not appear in the ALOS image whereas they can easily be seen on the SPOT-HRG image (although its resolution of 10 meters if lower than PALSAR's).

This is possibly linked with the fact that indigenous garden plots usually show a great diversity of cultures, and also to the fact that bare soil is very rare, fallen trunks occupying the garden for many years and then creating less contrast with the surrounding forest area. Polarimetric data (figure 3 and 4) offer a better view, but still very inferior to the precision of lower resolution optical data (like also CBERS-2 CCD, see figure 5). For instance, on figure 4, the remnants of the Perimetral Norte road begin to appear, but much less than in figure 5.

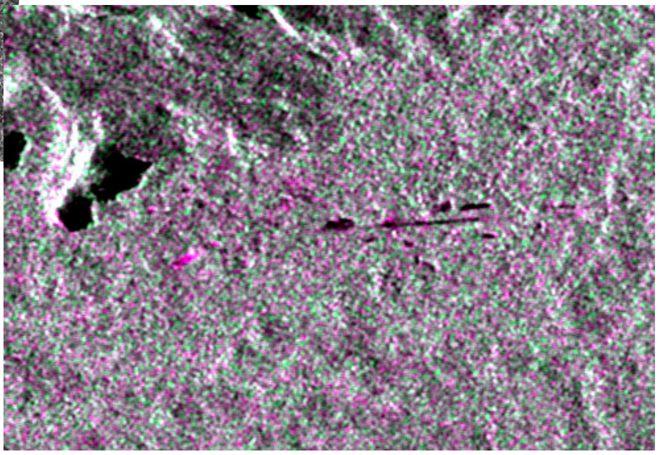

Figure 3. The Watoriki area (PALSAR FBS mode, R=pol1 G=pol2 B=meanB1-B2, image treated with Frost)

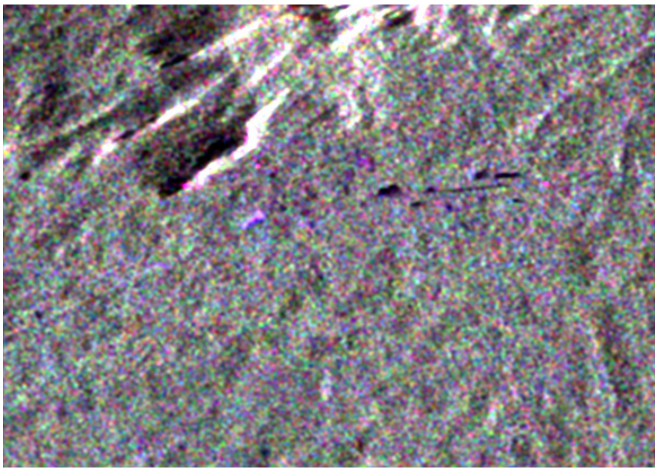

Figure 4. TheWatoriki area (PALSAR Polarimetry mode, R=VV G=HV B=VH, image treated with Frost filter + median 3x3)

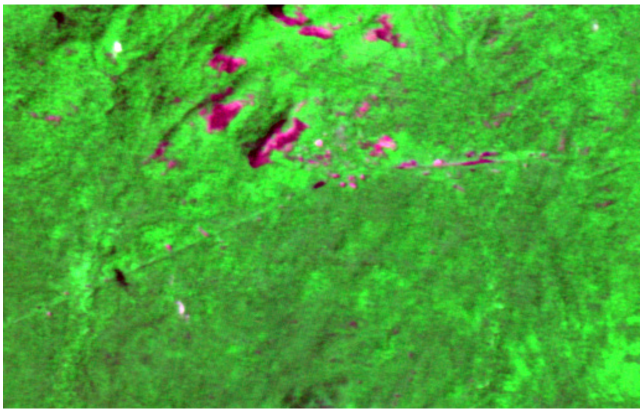

Figure 5. TheWatoriki area (CBERS-2, RGB=342)

As will be stated in the prospects section, it is also possible that the nature of the data used (amplitude vs complex) be involved in this poor result, and we shall try to improve it in the future with the analysis of complex data. As for now, only landing strips seem to be easily detected, a feature that could prove useful in the future for detecting invasions by wildcat gold miners (Le Tourneau and Albert, 2005).

As for the study of deforestation in the Ajarani region, ALOS images were evaluated as performing very well, especially in polarimetric mode (figure 6 and 7). Differences between two forest types (lowland forest and high forest) were much more evident on ALOS images than on optical data, probably due to the SAR sensitiveness to the geometry of the forest cover (lowland forests are much more uniform in height, giving a "flat" forest cover, whereas high forest areas see giant trees surrounding the cover, giving an heterogeneous cover). In figure 7, area between the two rivers is thus better shown apart from other forest area than in figure 6.

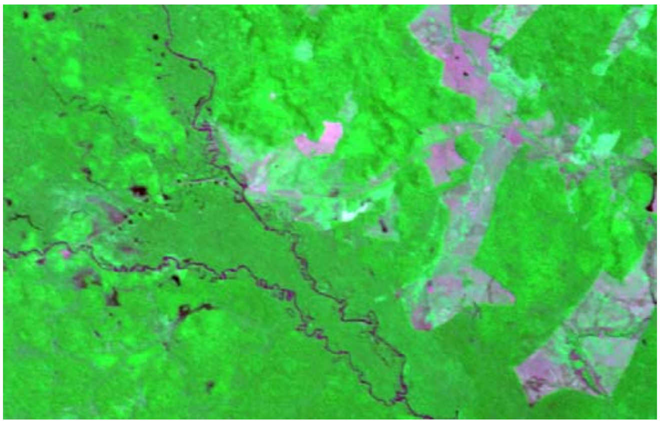

Figure 6. The Ajarani area (CBERS-2, RGB=342)

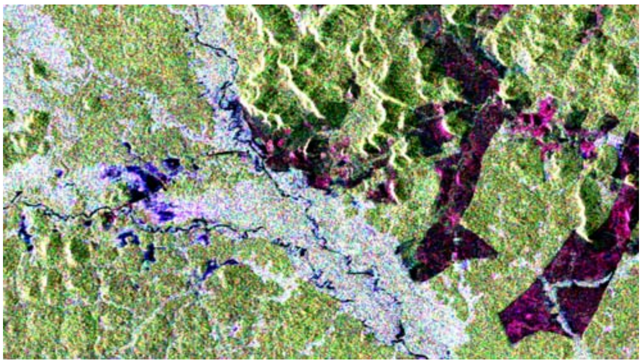

Figure 7. The Ajarani area (PALSAR Polarimetry mode, R=VV G=HV B=VH, image treated with Frost filter + median 3x3)

A supervised maximum likelihood classification (figure 8) was conducted on an extract of the PALSAR polarimetry mode image of the Ajarani area (after applying a Frost 3x3 filter in order to reduce speckle). Four classes were distinguished : water bodies (blue), lowland forest (coral), forest (green) and deforestation (maroon). The results were very good, as shown on figure 7. By comparing with the PRODES vector data, we proved that ALOS could give a much more fine grained vision of the deforestation. PRODES data, based on semi-automatical interpretation of optical data have a tendency to exaggerate deforestation in certain areas, especially hilly areas where the thinner forest is confounded with secondary regeneration.

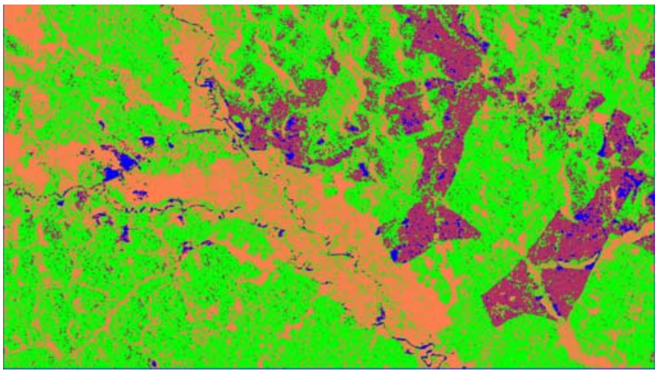

Figure 7. The Ajarani area (supervised classification of PALSAR Polarimetry mode image)

ALOS PALSAR, on the contrary, show much more detail on those areas. Detected deforestation polygon obtained from ALOS respect gallery forests (n°1 on figure 8) and hilly area (n°2 on figure 8). For that reason, even if, on a total of 5097 hectares deforested in our area of study according to the PRODES data, only 2207 were found to coincide with the detected, we stand that the figure obtained from ALOS is much closer to reality.

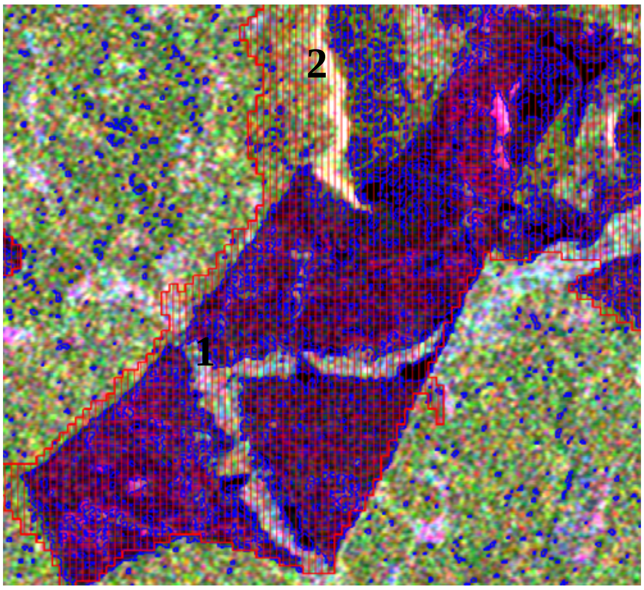

Figure 8. Detail of the Ajarani area with PALSAR image, deforestation from INPE (red) and deforestation detected in classification (blue)

Despite those very good results, one has to note that about 446 hectares were also classificated as being deforested on the ALOS PALSAR classification outside the areas considered by PRODES as being such. Some of those parasite polygons are concentrated around water bodies, other reflect the speckle in forest areas.

4. Discussion and prospects

Our tests have shown some potential for the use of ALOS PALSAR images in the analysis of deforestation and invasions. Nevertheless, those results must be confirmed on other test sites in the area of study, and tested against ground truth, which could be done during an already scheduled 2008 fieldwork. Also, classification of ALOS PALSAR data show a great number of parasite deforestation polygons, or dummies, that should be eliminated before results are considered fully satisfactory.

As for the results about detection and monitoring of indigenous settlements, results are not satisfactory. The acquired ALOS images do not show a great potential for that use, which is rather surprising given their excellent resolution and technical quality.

New methods should be tested in order to reveal indigenous settlements on ALOS images, especially using complex data instead of amplitude data. Unfortunately, those methods were not at our reach at the time of our ALOS research, and we had to turn to other more readily available remote sensing sources in order to fulfill our need for geographic information in the Yanomami area.

CONCLUSION

Our ALOS project as not as successful as we wished for a number of reasons. Some are linked to the SAR instrument, which is perhaps not very well suited to analyze very small objects such as indigenous gardens or small deforestation patches due to wildcat gold mining. Another reason is the geographical context, with many areas originally chosen for our research being mountainous and showing very important deformations in the ALOS images, turning them poorly readable.

The last point is linked with the configuration of our team, which is more specialized in social sciences than it is in remote sensing. We thought classical tools could be enough to exploit ALOS data and we encountered that new software was necessary, which was beyond our reach. For this reason we had to close our ALOS research even if the results achieved were under our expectations.

We feel anyway that ALOS data remain a reference in SAR remote sensing and we are looking forward to new cooperation which could provide us new tools or methods in order to exploit better those data.

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