MEASURING CLEARINGS AND TREE HEIGHTS WITH STEREO RADARSAT DATA IN A TROPICAL ENVIRONMENT[1]

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ABSTRACT

The paper demonstrate the applicability and the superiority of stereo RADARSAT data in a tropical rain forest environment by interpreting and measuring physical characteristics of the forest. Clearings and vegetation cover heights are measured on a fine mode RADARSAT stereo-pair using a digital stereo workstation. The results, which are good representative values of the truth on the ground, can be used as complementary information with other data to monitor the forest change and preserve the rain forest environment

1 INTRODUCTION

In the Amazon, there is an enormous need for mapping and monitoring of renewable and non-renewable resources. In fact, the increase in deforestation needs to be monitored on a regular basis. In this environment, where near-perpetual cloud cover occurs, monitoring vegetation changes and preservation of the forest become a challenge. Radar sensors present then a large advantage when compared to the sensor in the visible, and it is the main factor which motivates the choice of radar data for this application.

An ADRO project between the Instituto Nacional de Pesquisas Espaciais (INPE) and the Canada Centre for Remote Sensing (CCRS) was developed to address this problem, and to evaluate the potentiality of RADARSAT data for different geoscientific applications in Brasil, such as the forestry applications in the Amazon. One of the main objectives was

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to generate RADARSAT ortho-images, to integrate them with Landsat-TM ortho-images, and to extract reliable information in forestry (Amaral et al., 1996).

Most of the time, the canopy of the rain forest can be discriminated from the clearings on a single radar imagery. But, it is more difficult to discriminate between different types of clearings, such as active pasture, regenerated forest. In this context, the third dimension enhances the ability to interpret two dimensional imagery. The naturalness of 3D representation has major advantages to perceive and to extract geophysical information by combining the geometric and radiometric aspects of a stereo-pair.

The objectives of this paper is then to use a RADARSAT stereo-pair as a complementary tool to interpret and monitor the forest environment in Brasil. Using the radiometry of the two images and the geometry of the stereo-pair, clearings and tree heights can be qualitatively delimit and quantitatively determinate.

2 STUDY SITE

The study site comprises the Tapajós National Forest and its surroundings. It was restricted to the overlap area between RADARSAT images with the coordinates: from 55^{o} 05' to 54^{o} 48' west longitude, and from 02^{o} 55' to 03^{o} 00' south latitude. Tapajós National Forest is located in Sanitarém city, Pará state, Brazil, under IBAMA (Environment and Natural Renewable Resources Brazilian Institute) administration.

The geology of this region is basically characterized by continentals sediments formed by interlayed arenitos and argilitos. Deep, acid and erosion susceptible "Latossolo Amarelo Distrofico" soil and its variations, originated by tertiary sediments, dominates the region. Even occurring in flat terrain, the low fertility of these soils limits its use. Two morpho-structural units characterized the geomorphology of the region: the Amazon Debased Plateau, with altimetric values of about 100 m, and the Tapajós-Xingu Plateau with altimetry varying from 120 m to 170 m.

The rainy season is concentrated from February to May, mainly during March (358 mm) and April (361,9 mm) and dry season from August to November, when the month precipitation is less than 4% of the whole year. Temperatures ranges from 20^{o}C to 35^{o}C, with the lowest maximum temperatures during the rain season. (Hernandez Filho et al., 1993)

According to RADAMBRASIL (1976), Tapajós National Forest vegetation is divided into two sub-regions:

1. Amazon low plateau, which can be sub-divided in:

- Low Plateau Ecosystems, it occurs in low terrain, low slope, and clay texture predominant soils. A few economic wood species can be found;
- Low Dissected Plateau Ecosystems, it has an accentuate relief with dissected and narrow valleys, and medium texture soils. Lianas and palm species are frequent.

2. Xingu and Tapajós rivers high plateau - it is characterized by tropical dense forest with economic high value species.

According to Hoekman and van der Sanden (1987), in a plot over the Tapajós river high plateau, the trees high vary from 10 to 25 m, with emergent trees up to 30-40 m. Another plot over Low plateau presented lower trees height, with trees from 10 to 20 m.

Human activity is crescent in the region. Intensive deforestation activity took place along the Cuiabá-Santarém Road (BR-163), and some agricultural and pasture land use can be observed even inside the Tapajós National Forest boundaries.

The two RADARSAT images were acquired in fine mode with beams 2 and 5 (resolution of 8.8 m by 9.0 m) on May, 20 and 03, 1996 respectively, from descending paths. forest. It then generates a stereo-pair with an intersection angle of less than 6° over the full stereo-model. The F2 and F5 products were generated in SGF and SGX ground range format with a 6.25 m and 3.125 m pixel spacing respectively.

3 PROCESSING

The digital stereo workstation, the DVP, used in the data processing is based on a standard personal computer. It was originally developed at Laval University (Quebec, Canada) to process aerial photographs (Gagnon et al., 1990), and subsequently adapted at CCRS to process VIR and SAR data (Toutin, 1995). The stereo-viewing is related to conventional photogrammetric viewing with a split screen method and a simple stereoscope.

The digital data are first transferred to the DVP: it includes the SAR images and parameters (line, pixel number and spacing), the SAR parameters (viewing angles, direction, resolution), the satellite parameters (position, velocity) and the Earth parameters (semi-major axis, eccentricity). They are used to initialize the geometric modelling. The SGX image was also resampled at 6.25 m with a cubic convolution kernel to allow stereo-viewing with the SGF image.

Twenty ground control points (GCPs) are plotted in stereo with a plotting accuracy of about two pixels. The GCPs cartographic coordinates are obtained from the 1:100 000 topographic maps with a planimetric accuracy of 50-100 m and an elevation accuracy of 30 m. The elevation variation is between 10 m and 520 m. Furthermore, 14 tie points, without cartographic coordinates, are also stereo-plotted. They are useful to reinforce the stereo-geometry where there is no GCP.

Using the GCPs and tie points, an iterative least square bundle adjustment is performed to refine the geometric modelling parameters. The a-priori stereo mapping accuracy assessment is given with the residuals of the least square adjustment: 16 m, 18 m and 27 m are obtained in the X, Y and Z directions, respectively. Considering the cartographic coordinates accuracy, it is a good result, since this geometric modelling has already proved to be robust and consistent over the full stereo-pair (Toutin, 1995).

As a result, the stereo-model is generated from the raw images without any resampling, which does not degrade the image content, the stereo interpretation and extraction of the information. The extraction and measurement process is done in two steps. The first one is done qualitatively with visual and interactive interpretation. By combining the radiometric image content of both images and the depth perception in the stereo-model, 13 clearings borders are delimited in planimetry (Figure 1). Inside four of them, sub-areas are also delimited. Some areas and these sub-areas were impossible to extract in a single imagery and without depth perception.

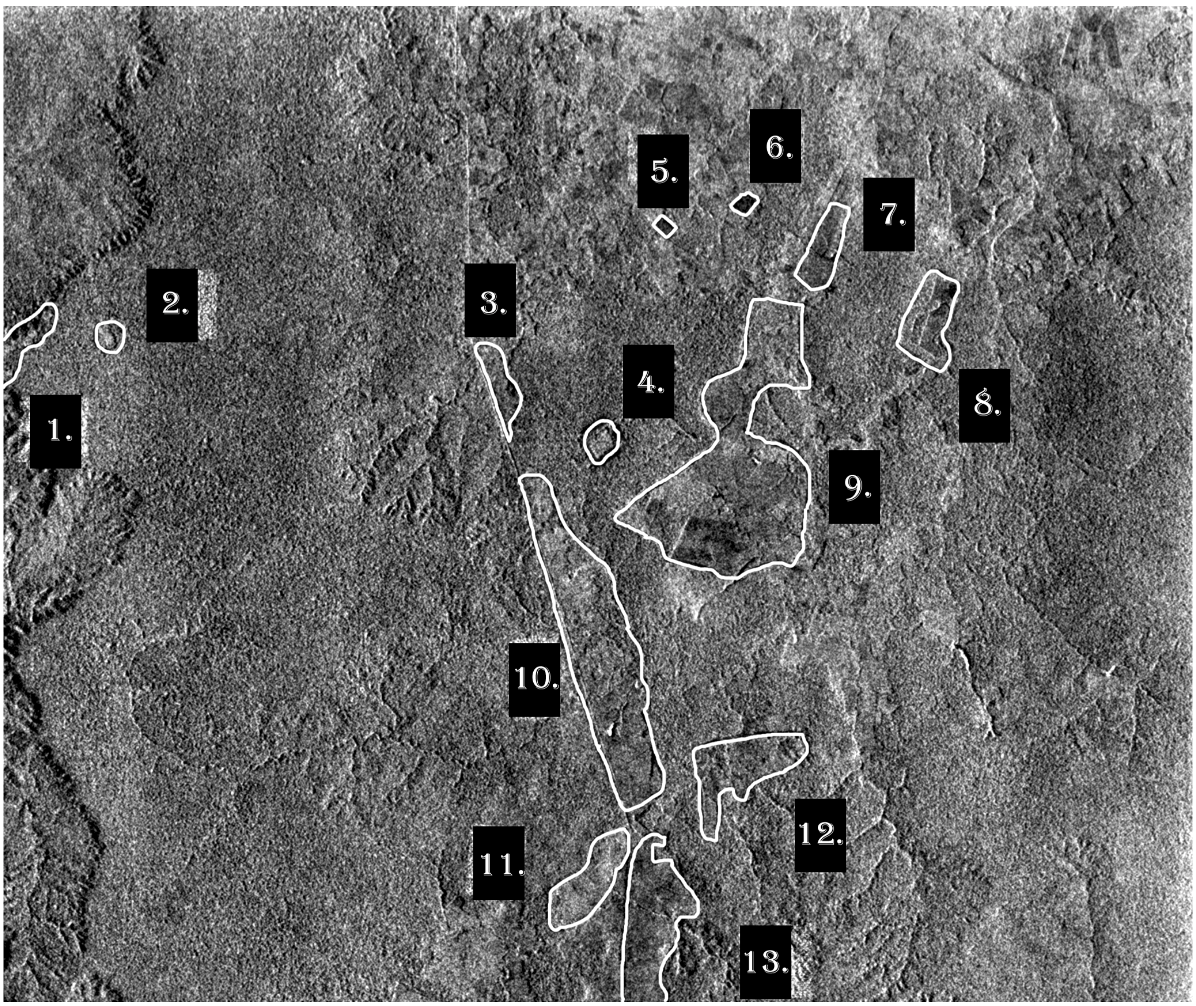

Figure 1. Clearings boundaries plotted from RADARSAT stereo-pair.

The second step deal with quantitative aspects. Since the stereo-model was oriented relatively to the user map projection system, computation with the extracted data can be performed, such as orientation, distance, surface, volume, or elevation variation. The determination of the trees height between clearings, secondary and primary forest is then possible. Stereo measurements of elevation (more than 460) are thus performed on both sides of the borders for each clearing and sub-clearings. Each measurement is realized three times to reduce plotting error. The difference in elevation is representative of the tree height.

If the clearing is perceived flat, the tree height of this clearing is computed from the difference of the means between all elevation stereo-measurements inside and outside the clearing. If the clearing is not perceived flat, the trees height of this clearing is computed from the mean of the difference between each two elevation stereo-measurements inside and outside the clearing. Table 1 is the summary of the results.

Table 1: Summary of the results (in meters) of the elevation stereo-measurements and the land cover type inside and outside the clearing edges.

Clearing	Clear-cut Elevation	Forest Elevation	Tree Height	Cover type inside	Cover type outside
1	152	164	12	regeneration	forest
2	136	155	19	forest gap	forest
3 A	136	145	9	dirty pasture	disturbed forest
B	133	152	19	dirty pasture	forest
4	183	194	11	regeneration	forest
5	233	251	18	bare soil	forest
6	292	306	14	bare soil	disturbed forest
7	278	306	28	bare soil	forest
8 A	204	216	12	secondary forest	forest
B	189	217	28	bare soil	forest
C	188	201	13	bare soil	secondary forest
9 A	155	177	22	dirty pasture	forest
B	154	177	23	dirty pasture	forest
C	167	184	17	bare soil	disturbed forest
D	153	165	12	pasture	disturbed forest
E	164	177	13	pasture	forest
10 A	110	138	28	dirty pasture	forest
B	92	138	46	dirty pasture	forest
C	94	137	43	bare soil	secondary forest
D	116	140	24	dirty pasture	forest
11	87	133	46	dirty pasture	forest
12	94	132	38	dirty pasture	forest
13	89	141	47	pasture	forest

Based on visual interpretation of Landsat/TM imagery (figure 2), the land use types where reported to both side of each clearing area extracted by the RADARSAT stero-pair. It was defined a vegetation content graduation from bare soil to forest.

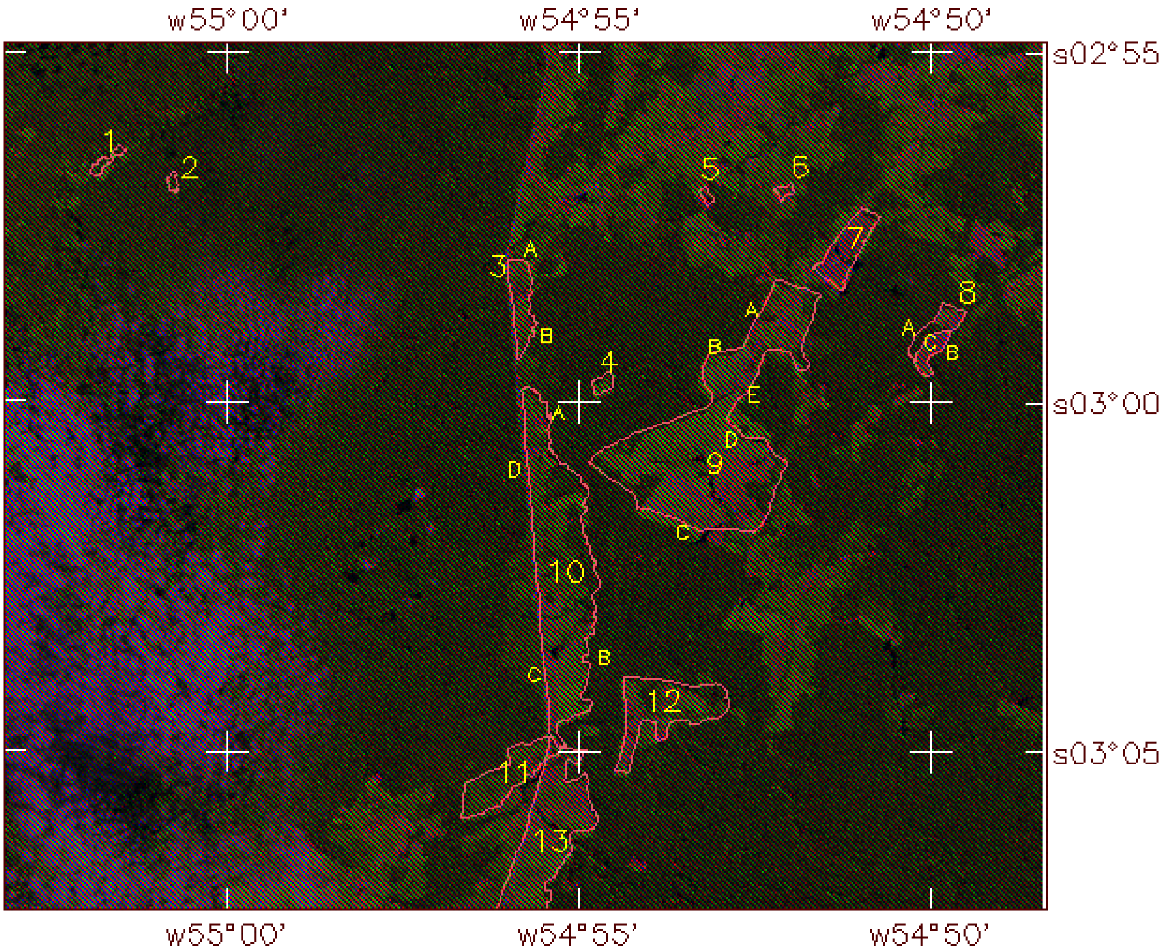

Figure 2. Clearings boundaries plotted from RADARSAT over TM/LANDSAT image.

Dirty pasture is related to the areas where some bushes and woody species can be found. Regeneration is the cover type between dirty pasture and secondary forest, there is an homogeneous woody cover but it does not have the same forest structure. Secondary forest represents clearcuts that was abandoned a long time ago and presents a cover type very close to the original forest but still can be forest distinguished. Disturbed forest is related to original forest with small clearcuts occurrences.

The results, presented on Table 1, are consistent with the reality: the computed tree heights are good representative values of the existing tree heights of the secondary and primary forest in this Amazon area. Exception must be done to heights bigger than 40m like clearings 10B, 10C and 13. There is any field report or description of emergent trees higher than 40m. The terrain altimetry must have affected the trees height measurements resulting in overestimated values.

Boundaries between forest and bare soil presented higher trees high values than boundaries between forest and other land use with some vegetation cover, like dirty pasture or secondary forest. When the outside cover is different from forest, smaller heights were reported to, suggesting coherence of the measurements.

A large amount of stereo-plotting and trees height measurements as well as field verification and calibration would emphasize these results. However, the methodology defined and the results obtained indicates the potential of RADARSAT stereo-plotting as a useful tool to plot and detect differences in vegetation cover height. Because the incidence angles of RADARSAT imagery are not efficient distinct to any height and direction of the edges, it would not be possible to drawn the limits with a single imagery view.

4 CONCLUSIONS

In a rain forest environment when cloud cover prevents optical data to be used to monitor vegetation change, radar data are the only source of information available. RADARSAT data with its different beam modes and positions provides a unique opportunity to acquire data with a large range of radiometric and geometric characteristics.

Furthermore, it provides the capability to generate various stereo-pairs of a specific area. Stereo imagery can be a complementary approach to extract information by combining the radiometric content of both images and the depth perception of the stereo. This advantage is much enhanced when no elevation data is available. Planimetric and altimetric features can be extracted in the stereo-model, since it provides a virtual 3D perception.

This paper has presented results of data extraction from a RADARSAT stereo-pair. Clearings and sub-clearings were first qualitatively identified and delimited using visual and interactive interpretation. It allowed to differentiate between different active pastures, secondary (regenerated) forest and primary forest. Quantitative computation are then done for these clearings. Finally elevation stereo-measurements were performed to compute the trees heights for each clearing and sub-clearing. Results (12 m to 38 m) are good representative values of the tree species in this Amazon environment.

The information obtained from stereo approach is complementary to other data obtained from remote sensing and field measurement. These information can aid the detection and measurement of the different vegetation cover types of areas with no access. Consequently, it can improve the planning and management of the tropical rain forest environment

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