RESOURCE MANAGEMENT WITH RADAR DATA IN TROPICAL ENVIRONMENTS: A CASE STUDY IN ACRE STATE, BRAZIL.

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ABSTRACT

In this study, we are presenting and discussing initial results of two SAR data evaluation projects in Acre State, related to deforestation of tropical rainforests for the establishment of cattle ranches and agricultural use. The applicability of spaceborne SAR for landcover/land use in this region is also discussed.

1. INTRODUCTION

Taking into account the ever increasing demand of environmental and resource information in a timely fashion and with the advent of spaceborne operational SAR systems (ERS 1 and 2, JERS and RADARSAT) during the nineties, two major SAR data evaluation Projects are being carried out in Acre by INPE, the Brazilian Space Research Institute, with foreign partners.
The first Project refers to the SAREX'92 Campaign (South America Radar Experiment), a joint INPE/CCRS (Canada Centre for Remote Sensing) Project, funded mainly by CIDA (Canada International Development Agency). The main objectives of the SAREX'92 Campaign were: 1. to obtain a C-band dataset with the Canadian SAR-580 in order to evaluate the capabilities of C-band SAR to detect and map relief features, forest types, clearings, burned areas, regrowth areas, flooding, and to simulate RADARSAT images from these data; 2. to promote "SAR literacy" among professionals in the area of planning and environmental/tropical resources management, both in Brazil and Latin America. The second Project refers to a joint INPE/DLR (German Space Agency) study, aiming to evaluate the use of ERS-1 SAR data to monitor changes in this characteristic tropical rainforest region, mainly due to burning.

The objective of this work is to present results of these on-going studies, as well as, based on available ERS-1 data and on RADARSAT simulations, to discuss the applicability of spaceborne SAR to study specific features of tropical environments like Acre State.

2. TESTSITE ACRE OVERALL DESCRIPTION

The State of Acre is located in SW Amazonia (Fig. 1), and has approximately 95% of its surface still covered by tropical rainforest , despite deforestation activities occuring in the southeastern part of it, mainly for cattle raising and annual plantations. Geologically this State is made up of a sedimentary sequence of Cenozoic age, the Solimões Formation, that includes mainly clays, sands, and lateritic crusts. This sequence is frequently covered by a non-differentiated detrital-lateritic cover as well as by recent alluvium of pebbles, sand, silt and non-consolidated clays. Due to the geologic substratum, the relief is frequently deeply eroded, forming hills with variable altimetry. Some sections along the road Rio Branco-Sena Madureira present small plateaus that are covered by lateritic crusts, but that are strongly eroded at its edges. A larger remnant of such a plateau, located to the west of Sena Madureira, can be easily detected by both airborne and spaceborne SAR systems (Figs. 2, 3, 4).)

The two main soil types of the area of interest, according to Valverde et al. (1989) are the Red Yellow Eutrophic Podzolic and Red Yellow Alic Podzolic. The first soil type, most frequent to the West and South of Sena Madureira is characterized by a relatively high content of Ca and Mg, while toxic components such as Al and Na are low to nil. The clays of this soil type are. highly colloidal. During the dry season it is characterized by deep cracks, becoming very slippery and easily erodible during the wet season. Being so, agricultural activities are feasible just in the shadow of the higher trees (agro-forestry), otherwise an intensive erosion takes place. The second soil type, very frequent

content and has consequently a very low potential for agricultural use.

The main vegetation types of this region, according to Valverde et al. (1989), based on field surveys by an IBGE/SUDAM/INCRA team, are: the semi-deciduous forest with "Castanheira" (Brazil nut tree) and the Evergreen forest with two undergroups: Evergreen forest with bamboo and Evergreen forest with Palms. Further details on the vegetation and on regrowth of vegetation from this region will be given in a companion paper, at this Symposium, by Santos et al..

3. THE SAREX CAMPAIGN IN ACRE

As one step in preparation for RADARSAT (Raney et al. 1991), SAREX'92 was established. The airborne C-band SAR-580 data acquisition campaign, at testsite Acre, was funded by CIDA. The data evaluation was partially performed in Canada by the Brazilian P.rincipal I.nvestigator (Kux et al. 1993, Saper et al. 1993) of this testsite and funded by CIDA, CCRS, INPE and the Brazilian National Council for Scientific and Technological Development (CNPq).
SAR data were obtained with the CCRS C-SAR sensor (Livingstone et al. 1988) in the three characteristic operating modes of the SAR-580: nadir, narrow swath and wide swath:
- nadir mode: 20km swath, incidence angles of nominally 0 to 74^0 with 6x6 m resolution,
- narrow swath mode: 18km swath, incidence angles 45 to 76^0 with 6x6 m resolution,
- wide swath mode: 60 km swath, incidence angles 45 to 85^0 with 10x20m resolution.

These SAR data were processed in real-time on-board. Photographic negatives were generated at CCRS using AIR-2 airborne image production system. Several of the interpretations reported in this paper were made from prints out of these negatives. For some sections of the testsite, the data were enhanced using digital processing to remove residual antenna pattern effects and geometric distortions, and to provide a contrast stretch optimized for the area of interest. Using a RADARSAT simulation package, developed by INTERA, (Canada), simulations of RADARSATt, fine and wide resolution modes, were made at CCRS and discussed in this paper (Figures 3, 6, 9).

Field verification data were also collected during the week of the radar data acquisition mission. Extensive 35mm photographs were made to document conditions at the time of the radar mission based on two flights in a Cessna 172 aircraft over the study areas. Ground control was made in sites of particular interest.

4. SAREX DATA ANALYSIS

An area of approximately 33,000 km^2 was imaged during the SAREX campaign in Acre. Due to its' size, a selection was made of some scenes that present characteristic relief, vegetation and hydrology features of the region under study. Data analysis was performed using a PROCOM-2 image enlargement equipment, as well as through visual interpretation of prints enlarged from the original negatives.

4.1. Section Sena Madureira - rio Purús - Rio Branco.

The Rio Purús, the largest river of Acre State, flows within a W-E floodplain, showing on SAR images (Figs. 2 to 4) two well-defined river terrace levels. The lower terrace, approximately 5-10m high, is characterized by several fluvial features such as oxbow lakes, meander scars and former river channels that are frequently covered by vegetation. The upper terrace is defined by changes of drainage patterns and is very well depicted from airborne SAR/C HH, wide swath mode data, (Fig.2). This image allows a good discrimination of drainage when the relief forms a flat plateau (Figs. 2 to 4). A high density of drainage prevents from a precise location of river channels and shows the typical SAR features of illuminated and shadowed slopes. The simulated RADARSAT scene (Fig. 3), in spite of the characteristic speckle, allows a good definition of the main relief/ and hydrologic features.. Figure 4 shows the same scene, taken by ERS-1 SAR.

Along the road BR-364 (Rio Branco - Sena Madureira) there are frequently larger, geometrically deforested sections, mainly cattle raising "fazendas", that can be well perceived on both airborne (Fig.5) as well as spaceborne (Figs. 6 and 7) SAR images. Taking into account the fast impoverishment of soils due to strong leaching of nutrients and erosion after deforestation, there is a need of continuos rotation on the use of pastures. The rotation is indicated on Figs. 5 and 6, where features such as pasture borders, smaller water reservoirs, access roads, regrown forest along creeks and lengthy geometric features along the pasture can be detected. Differences in the overall radar backscatter from one pasture to another can also be related to differing amounts of weed and brush growth, with the more overgrown pastures appearing brighter on the radar images. The corresponding ERS-1 scene (Fig. 7) gives an overview of the entire "fazenda". Noteworthy are differences in tone and texture between HH and VV polarized scenes (Figs. 6 and 7).

Closer to Rio Branco, an airborne SAR C HH, Narrow Swath Mode scene, (Fig.8) shows another example on the use of these data for geomorphologic and landuse studies. To the left the meandering rio Acre with its' typical meander scars, lakes and channels comes out quite neatly. In the centre of this scene, a larger cattle ranch, presenting water ponds and other details of drainage, is shown. Some details of regrowth can be recognized to the right of the deforested section. Even individuals of "Castanheiras", (white dots close to the dark shadow dots), at the right edge of the deforested area, can be occasionally detected. on Fig. 8. The simulated fine resolution mode RADARSAT scene (Fig.9) shows many of the features discussed above, but also trails (linear features) and smaller deforested areas for the plantation of annual crops can be detected.

4.2. Section at an area of "colocações" south of Rio Branco

The traditional extractive economic activity of Acre State has been, for over a century, the rubber tapping from Hevea Brasiliensis, the rubber tree. The small clearings, locally known as "colocações", where annual crops are planted by the tappers, can be detected on this airborne C-SAR narrow swath mode scene (Fig. 10). Furthermore subtle changes on the density of the drainage and consequently of relief can be perceived. A study on the detectability of clearings from the testsite Acre (Ahern et al. 1993) concluded on the minimum size of clearings that could be detected by airborne (C-band

SAR) and spaceborne SAR data. As for airborne SAR data, clearings of a few hectares can be detected.

5. THE DIGITAL CLASSIFICATION APPROACH OF MULTITEMPORAL ERS-1 DATA IN ACRE.

Based on a INPE/DLR cooperation project in Acre and on Landsat-TM investigations by Hoensch (1993) in this region, DLR started an ERS-1 Pilot Project on "Tropical Rainforest Investigation in Brazil using ERS-1 data", additionally funded by the German Agency for Space Research (DARA) (Scales et al, 1994). Considering the multi-temporal aspect, the information content of ERS-1 data for classifying rainforest types (dense and open), regrowth and present landuse is considered. Until now 6 datasets of ERS-1 data between April '92 and July '93 are available from this region.

5.1. The EBIS classifier

Unlike maximum likelihood classifiers, EBIS (for Evidence Based Interpretation of Satellite Data), developed by Lohmann (1991), allows the definition of each object class by a set of different descriptors, based on previously defined training areas. Besides Gaussian normal distribution, multinomial distributions are also supported by this classifier, which seems to be more adequate to classify radar data. When considering multinomial distribution, local scaled histograms are evaluated within a selectable window environment (5x5 up to 9x9) around the central pixel.

5.2. Results of forest/non-forest classification by ERS-1 data.

Unlike airborne C-band SAR data, ERS-1 SAR data with a ground resolution of about 25 m, has lost much of the textural information, which would be helpful to discriminate the rough rainforest canopy against pastures and regrowth. Being so, the choice of the adequate season for ERS-1 registration becomes more important. The radiometric contrast among rainforest and pasture or colonization areas was found to be higher during the dry season (Keil et al, 1993). Nevertheless, data from the wet season can give an improvement in multi-seasonal classification with the backscatter of the rainforest area staying mostly stable.

An approach to EBIS classification was made for an area around Sena Madureira. The monotemporal EBIS classification was successful for the separation of rainforest and pasture using May and June'92 ERS-1 data. Misclassifications were due mainly to relief effects, specially in hilly areas with different illumination/shadows along the drainage system. Problems also occured for the separation between rainforest and regrowth areas on former pastureland. In comparison to a classification with TM Landsat data, 93% of the forest area, but only 62% of non-forest area were identified by ERS-1 SAR classification in a subscene of this region (Scales et al. 1994). Promising results were found for the identification of regrowth areas, while using a multi-temporal/ seasonal EBIS classification, with ERS-1 data of April, May and December'92. The multiseasonal classification will be extended to a larger area by the integration of data obtained during a ground survey performed in June '94 in cooperation between DLR/INPE and University of Acre.

Acre is also a testsite for the SIR-C/X-SAR Mission. The multi-frequency (X, C and L bands) and multi-polarimetry (HH,VV and crossed polarization) cababilities of this experimental SAR system and particularly its' L band, will certainly indicate new options for the discrimination among land cover/land use in this region.

6. CONCLUSIONS

The availability of airborne C-band SAR (SAR-580), simulated RADARSAT and ERS-1 SAR data of the same region of Acre, leads to a comparison on the information content of these data. The minimum detectable size of the deforested areas, which can be well determined even in small clearings when using airborne C-band SAR data (e.g. Fig. 10) is still under study with ERS-1 SAR data. Data from ERS-1 SAR shows a high potential for the classification of rainforest, pastures and regrowth areas. The simulated RaADARSAT scenes shown (Figs.. 3,6,9) indicate that it would also perform well for land cover/ land use studies in this environment. Furthermore, the option of varying its angle of incidence, I which is unique for Radarsat and will permit the more detailed analysis of geomorphological features, particularly along river floodplains, a relevant information for the management of natural resources in a pioneer region like Acre.

The airborne C-band SAR-580 as well as the simulated RADARSAT data shown in this paper are being used successfully in Brazil, specially in Amazonia, to train remote sensing specialists and planners, among others, on the use of radar data for their work, an important technology transfer task from INPE in Brazil.

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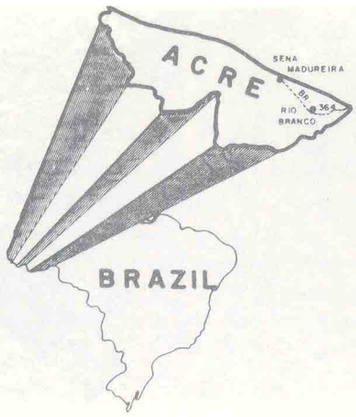

FIG. 1 - Localization of area under study

FIG. 2 - Airborne C-band SAR, HH, wide swath mode, Rio Purús floodplain, relief features W of Sena Madureira

FIG. 3 - Section of FIG. 2, RADARSAT simulation, wide resolution mode

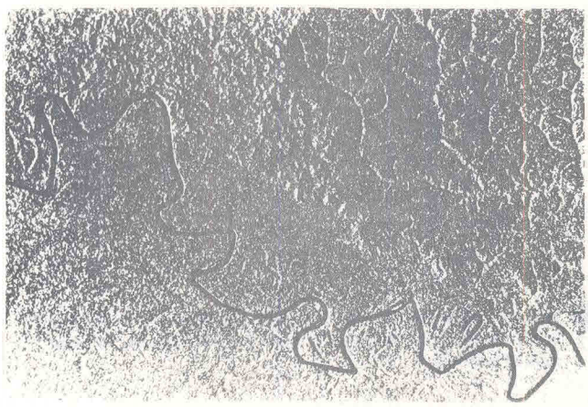

FIG. 4 - Equivalent ERS-1 scene of FIG. 3

FIG. 5 - Airborne C-band SAR, HH, narrow swath mode. Section of "fazenda", several landuse features can be detected.

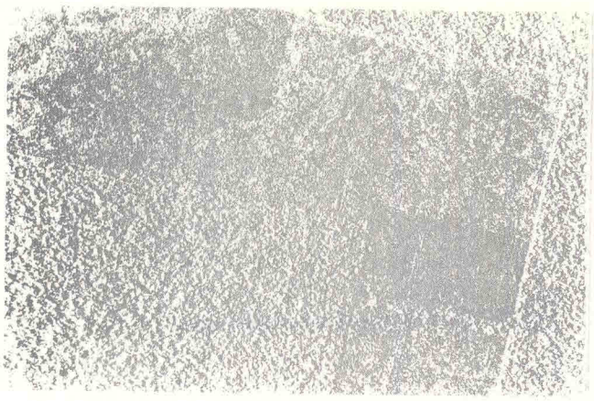

FIG. 6 - Simulation of RADARSAT image from Fig. 5

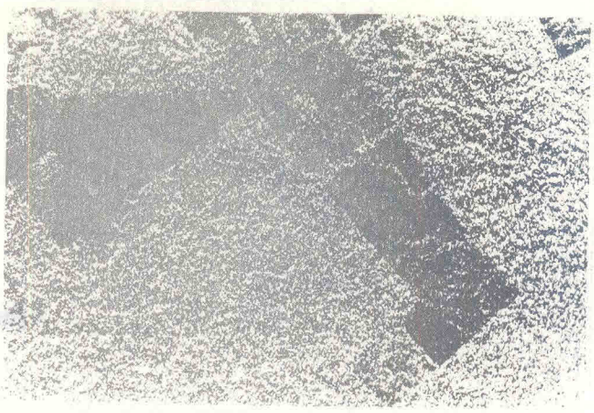

FIG. 7 - ERS-1 scene with overall view of Figs. 5 and 6. Note differences in tone and texture between HH and VV polarizations.

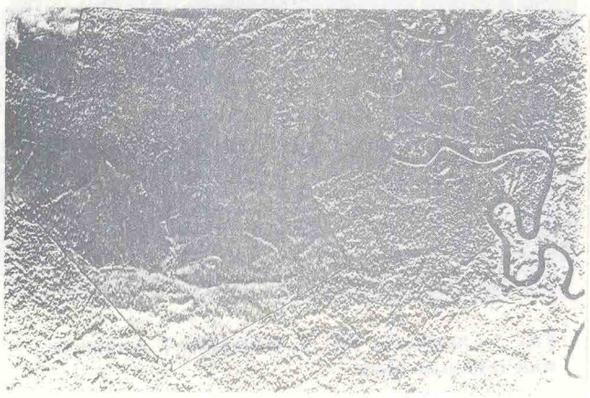

FIG. 8 - Airborne C-band SAR, HH, section along Rio Acre: hydrologic, geomorphologic and land use features are clearly detectable.

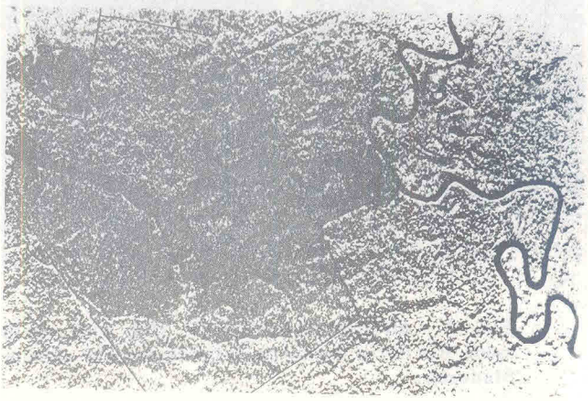

FIG. 9 - Simulation of RADARSAT, fine resolution mode, from scene shown in Fig. 8.

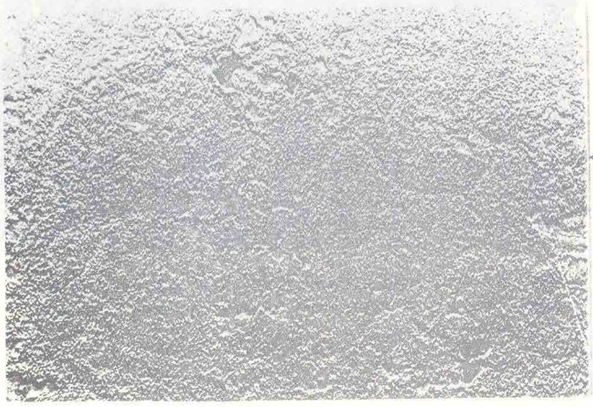

FIG. 10 - Airborne C-band SAR, HH polarized scene showing small clearings ("colocações") from rubber tappers, to plant annual cultures