MAPPING AREAS OF REGROWTH IN TROPICAL RAINFOREST USING A MULTISENSOR APPROACH: A CASE STUDY IN ACHE

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ABSTRACT:

The areas of regrowth of native species in the tropical rainforest within Acre State, Brazil, were characterized and mapped, using a TM-Landsat dataset from 1985 to 1992. ERS-1 SAR and airborne C-band SAR data were collected to evaluate the potential of these new sensor systems to analyze the vegetation regrowth. The results found indicate the feasibility to discriminate between two regrowth stages: initial and intermediate. The areal distribution of regrowth was stored as thematic maps in a GIS. Using the combined multi-sensor and multi-temporal dataset, it was possible to characterize the dynamics of the biophysical features of this environment. The main result of this work was the estimation of those areas under regrowth for the entire State of Acre (from all the deforested area until 1992 (11,050 square km), 97.73% are in the process of regeneration.

1. INTRODUCTION

The conversion of tropical rainforests to agricultural areas and pastures had a significant impact on regional and global level. Due to this, at the end of the eighties, a big concern was raised on the deforestation rates of these forests, which were then considered extremely high. In this frame, the Brazilian Government, together with the international scientific community, stimulated the use of remote sensing data, to find the most precise deforestation values for the Legal Amazonia. The Amazon recent data available indicate a total deforested area of about 435,900 km² (until May ‘92). The annual rate of gross deforestation decreased significantly from 0.50%/year, at the beginning of the eighties to 0.26%/year presently (Santos et al. 1993). Shukla et al. (1990) comment that the large-scale removal of the Amazonian vegetation would bring about changes in the regions’ hydrological cycle and climate, intensive enough so that the forests would not be able to recover itself.

In a larger frame, it is of interest to the national Brazilian scientific community to evaluate the role of Amazonia in the carbon cycle, specially considering two aspects: the emissions due to areal burnings and the carbon incorporation by the regeneration of secondary forest (Batista et al. 1993).

Being so, the objective of this work is to map with TM-Landsat data those areas under regrowth. ERS-1 and airborne C-band SAR data were collected, among others, to evaluate the potential of these new sensor systems to analyze vegetation regrowth. This study aims to be the first step towards the development of remote sensing techniques to study formerly occupied regrowth areas.

2. AREA UNDER STUDY

This study was performed in Acre State, SW Amazonia, with geographical coordinates 66° 35’ to 74° 00’ W and 7° 00’ to 11° 05’ S. Almost 93% of the State surface is still covered by tropical rainforest (dense and open) with a very frequent occurrence of the genus *Bambusa*. The deforestation activities are occurring mainly in the SE part of Acre, for cattle raising and annual cultures.

There are several Extractive Reservations in this State, mainly for the obtention of latex from *Hevea brasiliensis* and to collect Brazil nuts (Castanhas) found in this region.

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3. METHODOLOGY

The entire Acre State is covered by 14 TM/Landsat images of the following WRS orbits: 001/67, 002/66, 67, 68; 003/66, 67, 68; 004/66, 67; 005/65, 66, 67; 006/65, 66. Multitemporal TM color composite scenes (1985-1992) were analyzed to characterize those areas under regrowth. We understand “regrowth” of the landscape as the progressive development of vegetation, after the damage of the original vegetation, until it reaches a steady state, that could be different from the original vegetation. Taking into account that the deforested areas as well as the later abandoned areas have different sizes, ranging from large cattle raising fazendas of thousands of ha to agricultural fields with annual cultures of only a few ha, those areas with at least 6.25 ha were chosen, due to the spatial resolution of the system. The regrowth areas identified were put in a GIS, using MIR (Reduced Index Map) as a cartographic base (20 sheets at 1:250,000 scale for the complete State of Acre). In this database those areas of secondary vegetation were classified as “initial succession” with a regrowth age until 5 years and “intermediate succession”, from 5 to 12 years.

A short field work was recently performed along the road Rio Branco-Sena Madureira, in a section covered by TM-Landsat, ERS-1/SAR and SAREX data, to check those areas identified as regrowth. Furthermore 12 areas of regrowth were inventoried with the collection of the following data: flora composition, DBH above 3 cm (DBH above 10 cm at intermediate succession), total height, percentage of soil coverage. This reconnaissance inventory was made for arboreal or bush individuals along sections of 60x2m size.

An overflight of 3 hours was made to take 35mm photographs and for the reconnaissance of stratified classes along the strip imaged with remote sensing data used. The State of Acre is covered by several ERS-1/SAR overpasses. Furthermore some sections of it were imaged during an airborne SAR Campaign (Mission SAREX - South America Radar Experiment) in 1992, whose first results were reported by Kux et al. (1993).

4. CHARACTERIZATION AND ESTIMATION OF REGROWTH WITH TM/LANDSAT DATA.

Due to the type of management of this area, the variable soil fertility and also of the human influence, there is a certain differentiation of the structure of regrowth faces. The “initial phase” may be described as the degradation of pastures which are invaded by several species of bush and the arboreal stratum appears along some years of succession. According to Moran et al. (1993), these regrowth areas are different than the so-called “clean pastures” because they present more shadow. At the color composites of TM/Landsat (3B, 4G and 5R) this “initial” succession phase is characterized by a light green color of fine texture and this intensity and hue changes at the “intermediate” succession as soon as arboreal species dominate at the canopy. According to Moran et al. (1993) this category of regrowth presents a lower spectral intensity in the middle infrared, when compared to the “initial” phase. The level of activity of the photosynthesis, the structure and the foliar composition, they all seem to reflect the spectral variations identified at the thematic data.

At Table 1 those values of regrowth (in square km) for the “initial” and “intermediate” phases at each MIR from Acre State, are shown. The spatial distribution and the estimation of those areas of secondary vegetation refer to those areas identified on the images until 1992. According to INPE (1992) the annual rate of gross deforestation in Acre State in the timeframe 1990-91 was of about 380 square km. According to the study presented here, this rate dropped to 327 sq. km from 1991 to 1992, accumulating a total deforested area, until now, of about 11,028 sq. km for this entire State. From this total of deforested area, 9.73% are in the regeneration process that correspond to an area of 1073.570 sq. km (808.462 are “initial regrowth” and 265.108 “intermediate regrowth”). The decrease of the deforestation rate is due, among other factors, to a reduction of governmental subsidies and to a beginning consciousness of rational land use by the local farmers.

At Figure 1 one can see a vegetation profile showing a typical regrowth area (intermediate level). This area is located at 68°31’ 38” W and 9° 13’ 21” S. It is a section that was managed in the past as an agricultural area and then abandoned once, and today it is in the intermediate phase of succession. Dominating species are Dicliptera peruviana, Ochroma pyramidale, Cecropia sp. There is a definition of an arboreal structure where the higher individuals have, in average height of 12 m. In further works a series of data from this inventory will be analyzed in detail and correlated to multi-sensor data.

5. DISCUSSION ON THE CONTRIBUTION OF SAR FOR THE ANALYSIS OF REGROWTH AREAS

In order to organize the discussion on the contributions of SAR to the analysis of regrowth, we considered large regrowth areas (i.e. mainly cattle-keeping “fazendas” with several thousands of ha) and medium-sized regrowth areas (typically 50-100 ha large lots of agricultural projects) in the area under study.

As for the discrimination of large deforested areas for pasture, specially on gentle rolling to flat terrain, the use of both airborne and spaceborne SAR data is very promising. It was found that VV polarized data, narrow swath mode from C-band SAR 580 is quite useful to discriminate among pasture and overgrown pasture with weeds and bush, i.e. initial regrowth phase. An older regrowth (intermediate phase) would show, for visual interpretation, a more pronounced roughness; an useful criteria to discriminate among original rainforest, regrowth areas and pasture with these SAR data.

ERS-1/SAR data has shown to be useful for the classification of forest and non-forest areas in Acre, specially when considering a multi-temporal approach, as discussed in a companion paper at this Symposium by Kux et al. (1994). Areas of regrowth from former plantations of annual crops, can be well discriminated on airborne C-band SAR, VV polarized data. ERS-1/SAR data is still under study for the evaluation of the minimum size of clearings and regrowth to be detected with these data. Nevertheless, until now the best approach to detect regrowth areas in Acre, has been the
merging of TM-Landsat channels 3,4 and 5 with airborne C-band SAR data, considering the IHS (Intensity/Hue/Saturation) transformation. Herewith the multispectral information of the optical sensor is merged with the textural information of the SAR.

One of the problems related to regrowth that is still to be properly addressed, refers to the differentiation of regrowth due to relief features. In this case regrowth would be related to local hydrological and pedological conditions, and we are expecting that SAR data would give a contribution to this important issue.

6. CONCLUSIONS

It should be emphasized that until now, there are quite a few studies in Amazonia, related to regrowth using, among other techniques, remote sensing data. With this study we expect to give a first step towards the solution of the areal and multitemporal representation of regrowth cycles from a testsite of Amazonia.

TM-Landsat data strongly contribute for these studies, specially taking into account its spatial and multispectral characteristics. The multi-temporal characteristics of optical sensors like TM-Landsat is somehow hampered due to the high cloud coverage of Amazonia.

Nevertheless, this gap could be filled out by SAR. Based on the present experiences with SAR data in Acre, we foresee a strong contribution of these sensor systems, specially for multi-temporal analysis along the hydrologic year. This also refers specifically to Acre, because this region of Amazonia has a well-defined dry season of 3-4 months, when leaf fall occurs in several species. Furthermore, the availability of multipolarization (HH, VV and cross-polarized data from some sections of Acre) and multi-frequency (C, L and X bands) data from this region, will permit a strong impetus towards multi-temporal thematic classification of regrowth areas.

REFERENCES


TABLE 1 - ESTIMATION OF REGROWTH AREAS IN ACRES STATE, BASED ON LANDSAT/TM DATA

<table>
<thead>
<tr>
<th>MIR</th>
<th>REGROWTH AREA (sq. km)</th>
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<tbody>
<tr>
<td></td>
<td>Initial</td>
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<tr>
<td>182</td>
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<tr>
<td>209</td>
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</tr>
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<td>312-A</td>
<td>13.12</td>
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1 - CECROPIA sp.
2 - COCHLOSPERMUM sp.
3 - OCHROMA PYRAMIDALE
4 - DICTYOLMA PERUVIANUM
5 - OXALEA sp.
6 - PTEROCARPUS sp.
7 - GUATTERIA TOMENTOSA
8 - E. DUGUETIA
9 - PALICOURA LAGESII

FIGURE 1. "Intermediary" regrowth profile along the road Rio Branco-Sena Madureira (Acre).