# CANADA'S TROPICAL FORESTRY INITIATIVE IN LATIN AMERICA - AN AIRBORNE SAR PROGRAM

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## Abstract

In April 1992, the CCRS Convair 580 flew a C-Band airborne radar mission to six Latin American countries, as part of the ESA-sponsored SAREX-92 Campaign. Under its Tropical Forestry Initiative, CCRS conducted major cooperative research programs in three of these countries, with a smaller program in a fourth. Applications research for the sites flown with the C-Band radar included forestry, agriculture, geology, and hydrology among others. This paper will outline the aims and objectives of the Tropical Forestry Initiative research programs in Brazil, Venezuela and Costa Rica. The preliminary results of some of the data and interpretations as well as comparisons with ground verification information from some investigation sites will also be highlighted.

Key Words: Canada, Venezuela, Brazil, Costa Rica, Radar, Tropical Forestry.

## INTRODUCTION

Global monitoring by radar satellites offers an opportunity to make a substantial, positive contribution to sustainable land use management, particularly in areas of tropical forests. As part of its Tropical Forestry Initiative (TFI) in Latin America, the Canada Centre for Remote Sensing (CCRS) is conducting research projects in Costa Rica, Venezuela, Brazil and Guyana to investigate the use of C-Band radar in monitoring moist tropical forests and their environs. The airborne data is being evaluated in its own right, as well for simulations of the data from radar satellites, in order to make the benefits of the satellite data available to the widest possible community of users.

Canada's TFI in Latin America is associated with the Synthetic Aperture Radar Experiment '92 (SAREX '92) coordinated by the European Space Agency (ESA). Canada is making a significant contribution to this initiative, through provision of its expertise in radar data collection and analysis, technology transfer and training.

Some of the countries associated with the CCRS initiative have participated in several similar projects. Others are in the early stages of utilization of remote sensing. All countries have placed a priority on utilizing all the most modern techniques and applications to obtain the best value for its investment for their future growth and development. Each government has indicated that it is prepared to commit resources over a relatively long time-frame in order to see this and similar projects through to success.

### Objectives

The areas identified in the various countries have been selected as they are representative of large areas of the country. They are also relatively well-known from studies which have been conducted on the ground, and which will be continued, are relatively easily accessible, and contain the varied types of terrain and vegetative cover that is most suited to radar data research programs. As such, they contain the typical mixtures of types of terrain and land use variability that make them the most productive from a radar data analysis viewpoint. All these areas are important to participating countries from the point of view of future development and land use management.

Experiments in all countries collected data in all three swath modes - wide, narrow and nadir, depending on the particular application specialty.

Forestry and Agriculture:

1) To test the ability of SAR airborne data to differentiate between different types of tropical vegetation classes, based on visual analysis and digital image processing, taking into account textural, tonal and contextural attributes of the SAR scenes, using both ERS-1 and RADARSAT simulations.

2) To evaluate the capability of SAR to infer vegetation attributes such as biomass, canopy structure, and identify natural clearings, mining activity, etc.

3) To investigate the best approach to integrating SAR digital data with optical remote sensing data (TM-Landsat and HVR-SPOT) to improve the discrimination and characterization of tropical forest vegetation classes.

4) To test the use of terrain descriptors derived from DEM 's (digital images of elevation and slope) as an ancillary data set to be used in the extraction of information from the SAR Digital data.

5) To conduct comparisons of SAR data, especially on the geometry, texture and context of phyto-physiognomical units, with existing information from TM-Landsat and SPOT.

Hydrography:

1) To determine land-water boundaries in and under forested areas.

2) To delimit seasonally flooded areas which create a floodplain-type environment.

3) To delimit floating macrophyte stands in reservoirs, rivers and lakes, and define their relationships with other vegetation types, and to discriminate between areas of different macrophyte genus/species.

4) To determine if radar data can be used to discriminate between classes of vegetation and dead or submerged trees, as well as mixtures of them.

Geology:

1) To evaluate the capability of SAR data in different configurations (ERS-1 and RADARSAT simulations) to discriminate between different geological structures.

2) To evaluate the performance of SAR data from coverage parallel and normal to geological structures,

to aid in improving the detection and characterization of geobotanical patterns, and to characterize rock unit types and structures.

3) To investigate the best approach of digital enhancements and merging techniques of SAR, TM-Landsat and geophysical data (aeromagnetic and gamma ray) for lithological discrimination, structural mapping and geobotanical applications.

The areas which are being investigated in the various countries are described briefly below.

## BRAZIL

In Brazil, the four sites studied include a national forest, a large lake created by hydroelectric dam, a major mining region, and an area of mixed agriculture, ranching and rubber tapping (Fig. 1).

### Pojuca

This site lies in the Carajas Mineral Province. It has extensive deposits of iron, gold, manganese, copper, zinc, nickel, tin and bauxite. Brazilian researchers have been carrying out a long-term geobotany investigation. The area is an ideal site to test the performance of SAR imagery in a "difficult" mountainous terrain, where illumination conditions will vary appreciably due to surface topography. The vegetation of the region is typical of tropical upland rainforest, and three major ecological regions are recognized in the test area.

### Acre State:

The sites in Acre State lie on an plateau with rolling to flat relief and a predominantly NE-SW drainage pattern. Tropical rainforest is the main vegetative cover. Cattle ranching, and secondarily, settlement projects, are the prime causes of forest clearing in Acre State. Small farming projects in the regions have been hampered by the fragility of the soils and vegetation.

### Tucurui:

The Tucurui site is located in the Tocatins River Basin, which is a predominantly flat area covered by tropical rain forest. In 1985, a hydroelectric dam was constructed on the Tocatins River, and an area of approximately 2,340 km2 was permanently flooded. The Tucurui Reservoir has a water volume of some 45.8 km3, and is up to 70m deep.

The Tucurui test site has undergone extensive change since the dam created the reservoir. The flooded forest areas are under a gradual and constant process of decomposition and provision of nutrients to the reservoir. The increasing nutrient levels caused by the intensive land use and water level fluctuation, together with the decrease in speed of the current are largely responsible for the growth of large floating macrophyte stands.
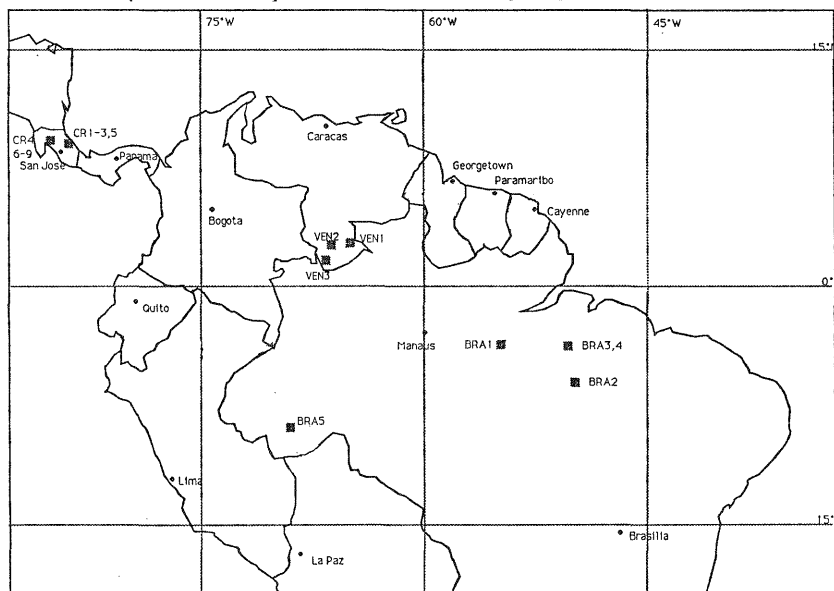
### Tapajos:

The Tapajos test site, in the Tapajos National Forest, is located in Para State, near the Municipality of Santarem. The site comprises approximately 600,000 hectares of tropical forest. At the border of the National Forest there are several areas which have been deforested as a result of human activity. Geomorphologically, the area ranges from areas of lowlands with low slope variances to intensively dissected plateaus and poorly-textured soils, to highlands characterized by dense tropical forest with trees having a high commercial value.

## VENEZUELA

Research projects in Venezuela were carried out in the Federal Amazon Territory, near the headwaters of the Orinoco River (Fig. 1). The entire region is covered by dense tropical forests, with areas of natural savanna, areas subject to periodic flooding, and isolated clearings used for shifting agriculture by local inhabitants. There are a few villages in the region, with some airstrips, but there are no local industries or infrastructure.

In Venezuela, the two sites are in the Federal Amazon Territory, within the region declared a World Biosphere Preserve by the Government of Venezuela, near the border with Brazil to the south. Detailed classification



| VEN 1 | Sierra Parima |
| VEN 2 | La Esmerelda |
| VEN 3 | Casiquiaire |
| BRA 1 | Tapajos |
| BRA 2 | Pojuca |
| BRA 3 | Tucurui |
| BRA 4 | Tucurui Scansar |
| BRA 5 | Acre |
| CR 1 | Atlantic Coast |
| CR 2 | Limon |
| CR 3 | Rio Barbilla |
| CR 4 | Pacific Coast |
| CR 5 | Platonar |
| CR 6 | Laguna de Arenal |
| CR 7 | Guanacaste |
| CR 8 | Central Valley |
| CR 9 | Osa Penn. |

Figure 1: Test site locations.

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of the forests in the entire region has been done by researchers in Venezuela, and this information will be invaluable in utilizing the radar data for forest discrimination. Venezuela has recently undertaken a GPS survey in the area, and this will provide extremely valuable control information for the joint research program.

La Esmerelda:

The topography of the region varies markedly from the relatively flat Orinoco River floodplain, to a near-vertical mesa ("Tepuis") which rise some 1200 m from the floodplain floor. The top of the Tepui is constantly cloud-covered, and the radar imagery has provided the first detailed view of its almost inaccessible top. Aside from the savannas in the lower regions, and the areas cleared for local agriculture, the region is dominated by lowland tropical forest with a near-continuous canopy.

Parima:

The eastern area consists of a tropical forest highland on an incised area of the Guyana shield, with the vegetation markedly controlled by elevation. As well as "normal" highland tropical forests, the area contains unique highland fern-dominated savannas as well as smaller Tepuis similar to the large one at La Esmerelda.

Costa Rica:

In Costa Rica, virtually all government institutions are involved in the various projects, including such groups as the national mapping agency, the hydroelectric company, the forest ministry, irrigation development ministry and the Costa Rica coffee and banana institutes. The projects in Costa Rica ranged from agriculture and forestry to hydroelectric development and topographic mapping, and covered a large part of the country (Fig. 1).

Areas of particular interest in Costa Rica include the province of Guanacaste , which includes both moist and dry tropical forests, irrigated and dryland farming, and pastureland; the Central Valley with its extensive agricultural development, several mountain ranges of volcanic origin, and the Atlantic lowlands, with large areas of moist tropical forests, extensive banana plantations, and mangrove forests. The variability of the Costa Rican topography, which is locally dominated by volcanic cones and peaks, generated particular challenges for image collection, as they are aereally restricted, topographic "spikes" that dominate the landform. However, they are in continuous use for agricultural purposes. Following extensive deforestation, primarily for cattle raising, since the 1960's the Government of Costa Rica has designated some 20% of the nation as national parks and other protected areas. Eco-tourism is becoming one of the most important sources of foreign exchange. One of the overall goals of this project in Costa Rica is to determine the contribution radar remote sensing and associated technologies can make to sustainable, multiple-use resource management in a complex geographic and social environment.

Preliminary Results

The data is of uniform high quality, and already researchers have been able to discriminate different vegetation classes within the forests, variability in types of agricultural activity, plantations, major and minor geological features, natural and man-made clearings and relatively minor variations in drainage patterns.