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SOME RESULTS ON THE USE OF THE LANDSAT-1 MULTISPECTRAL IMAGES

by the Soil, Mineral and Sea Resources Groups and presented by Renê A. Novaes of the Institute for Space Research (INPE), São José dos Campos, São Paulo, Brazil

ABSTRACT

The Brazilian Remote Sensing Program is presently being developded by three Institutions: 1º) The Institute for Space Research-INPE, designated by the Brazilian Government to be the main civilian agency in the development and application of space researches; 2º) the Ministry of Mines and Energy, with the RADAM Project which surveyed 4.5 millions Km^2 of the Amazonas region (through the services of LASA), using a side-looking airborne radar and 3º) the Ministry of Industry and Commerce, through the Brazilian Coffee Institute which develops a forecast project and a coffee plantation control. It is important to note that the latter two parts, today under the competence of the mentioned Ministries, did originate from INPE first efforts on the occasion of the Remote Sensing Program definition.

In the INPE Research Department there exist seven Research Coordinations and among them is the Coordination of the Earth Resources Research Projects (SERE) which takes care of the Application of the Remote Sensing Technologies. The main objective of the Coordination consist in: Establishing methodologies associated to the effective uses of remote sensing techniques.

Nowadays the Coordination concentrates its main efforts in the utilization of the LANDSAT-1 images and has already obtained effective and practical results as: 1) Brazil Natural Vegetation Map, being prepared in charts of 4 by 6 degrees, to the millionth; 2) The Sea Resources Group developed a study of the dynamics hydro/oceanographic processes of coastal and lagunar waters using the multispectral images of the LANDSAT-1 and SKYLAB (S-190-A). The Patos Lagoon at the Rio Grande do Sul State, to the South of Brazil, is the area under study; 3) A third importat result is the Mapping of the Brazilian Geological Structures. In the likeness of the vegetation map this one is being prepared in quadrangles of 4 by 6 degrees, in the scale of 1:1,000,000, mainly using the LANDSAT-1 multispectral images and data of other sensors.

INTRODUCTION

In the Institute for Space Research there exist seven Research Coordinations and among them is the Coordination of the Earth Resources Research Projects (SERE) which takes care of the Application of the Remote Sensing Technologies. Presently the SERE is formed by seven functional groups: Soil Resources Group, Mineral Resources Group, Sea Resources Group, Geography Group, Geodesy Group, Automatic Data Interpretation Group and Special Activities Group. These groups are organized so that it permits an inter and multidisciplinary research work. These are over 100 in-house researchers in the area of remote sensing.

The main objective of the Coordination consists in: Establishing methodologies associated to the effective uses of remote sensing techniques.

Nowadays, all the groups of the Coordination concentrates its main efforts in the utilization of the LANDSAT-1 images and has already obtained effective and practical result as: Brazil Natural Vegetation Map, Regional Geological Mappings and Mapping of the Brazilian Geological Structures, Study of the Hydro/Oceanographical Processes of the Patos Lagoon, and more than ten projects already in development.

It is intended to succinctly present here results obtained in the Mapping of the Brazilian Natural Vegetation and of Geological Structures, to the Millionth, as well as a Study about the Dynamic of the Hydro/Oceanographical Processes of the Patos Lagoon:

1. Mapping of Natural Vegetation Distribution over Central Eastern Brazil from Data Obtained by LANDSAT-1.
2. Hydro/Oceanographical Process of the Patos Lagoon from Data Obtained by LANDSAT-1 and SKYLAB.
3. Mapping of Geological Structures using the LANDSAT-1 images

1. MAPPING OF NATURAL VEGETATION DISTRIBUTION OVER CENTRAL EASTERN BRAZIL FROM DATA OBTAINED BY LANDSAT-1.

1.1 - Introduction

The difficulties of implementing a map showing the distribution of the natural vegetation of the whole Brazilian territory have frequently been reported. The problem lies mainly in the large size of the country, which lacks sufficient roads to penetrate the unknown areas, and the lack of specialists to execute this work and to present a reasonable scientific level. Generally speaking, the main difficulties are financial and human resources and the time factor. For a country looking forward to its development program, land-use information is essential. It is not an easy task to collect enough detailed data about this subject when the basic ecological knowledge is not well known.

The Multi-Spectral Scanner (MSS) of LANDSAT-1 offers information about

the land surface in four bands. Through multi-spectral analysis, sufficient ecological data can be obtained about land form vegetation density, drainage pattern, relief, and other essential data of a global nature.

1.2 - Objectives

a. Offering to the end users: planning, public service, investment and research organizations, understandable data with a global nature for national development policy.

b. Using natural vegetation,as a result of natural reaction,to understand environmental factor functions.

c. Identification of the vegetation habitats through multispectral analysis at the scale of 1:1,000,000.

1.3 - Methodology

It was necessary to establish an interpretation key over some test areas which have well known vegetation types and have been mapped by more detailed remote sensing techniques. By studying the spectral response of each habitat in these test areas, an extrapolation to other unknown regions is possible. Using this method mapping of isolated regions could be done at an accurate level in a relatively short time and in an economic manner. By comparing the reflectance in each band in view of the different considerations, and having sufficient background about vegetation cover, its physiognomy, leaf morphology, soil properties and the geomorphological features of its habitat, a precise identification can be made with the MSS imagery. To use the maximum possible quantity of information offered by the system, a special legend was developed in a manner useful to specialists in different fields. The legend specifies the biological components, climate, geomorphology, wildlife, and other environmental properties of each habitat (Table I). The purpose of the legend is to identify the different vegetation habitats by translating information on reflected energy into ecological terms. It is divided into three physiognomy classes: Forest, Cerrado and Campo. Climatically it is divided into three categories: rainy (pluvial), seasonal, and mixed.

Looking further to the end users, it was essential to present more detailed data to help them in making their decisions more accurately. A land-use table has been developed, offering more detailed information about each habitat. The information is obtained by consulting some specialized basic reports besides multi-spectral data. They are: climate, topography, soil depth, soil fertility and soil permeability. By assigning a range or degree for each habitat according to each parameter, it was possible, through the integration of the information about each habitat, to establish a scientific priority of the investment in general and to specify the best land-use for each habitat, in the major field of land-use activities under the Brazilian conditions. If there is any need to consider some additional local parameters, then the decision makers should take it in their consideration to modify the priority, if necessary. Also if there is a need to base the work on more detailed information for a specific region, then the same methodology can be used with more accurate sensors over the region to suit the end user's requirements.

1.4 - Results

a. The final output of this work is having transferred the reflected energy units into a common understandable language. It shows the following vegetation distribution: The Atlantic coast is the eastern boundary, with the presence of sand dunes in a discontinuous strip, broken sometimes by swamps or directly by the Atlantic forest. Moving toward the west, the mixed evergreen forest and the mountain campo appear on the mountainous topography. Northward, toward the west, the sclerophyllous vegetation and forest can be found. If there are deep soils, then cerradão will be found. Shallower soils would be covered by cerrado. On the slight slopes the vegetation cover is campo limpo. The sharp slopes do not permit sclerophyllous vegetation to grow. Here there is campo vegetation on the slopes with mixed forest frequently present. In the northern part of the region, on the inter-mountain depressions, the canopy is spiny forest: Caatinga. The mixed semi-deciduous forest, mata seca, is also a plateau vegetation, but is also found over richer soils in some shallow wide depressions, especially near rivers.

b. It is therefore possible to get the basic ecological information, presented on the map, through the MSS imagery. Geographical location of the mixed forest proves that it is a transitional geomorphological zone between the Atlantic forest and the cerrado. This agrees with the Brazilian geomorphological explanation of AB'SABER.

c. The same map proves that the mixed forest is an ecoton between the evergreen, and the coniferous forest, which agrees with the ecology point of view of EYER.

1.5 - Discussion

We have classified the end users of remote sensing technology into: special research institutes, governmental planning authorities, public service agencies, and investment and development organizations. The MSS imagery has been shown to offer enough multispectral data to be used to obtain basic ecological information using a well oriented legend and interpretation key.

The relation between the vegetation cover and its environment also provides information for the other specialists, who are concerned with natural resource investment and management. The fact that a large area can be scanned in a short period of time is an important advantage in multispectral interpretation. It can also provide information for a large area under the same physical conditions, such as: sun elevation angle, air temperature, and humidity, which may change the reflectance of the vegetation as it adapts its physiological functions to the environment. Care must be taken to compare each frame independently since different frames are scanned under different atmospheric conditions.

The special research institutes can work inside each habitat to get more detailed data and can compare the different locations of the same habitat to better understand the different phenomenas.

Governmental planning authorities can use the habitat as an indicator to

TABLE I - LEGEND

1.0 - Forests

1.1 - Rain
1.1.1 - Evergreen, Broadleaved
1.1.1.1 - Amazonic: a - Terra firme (UPLAND)
b - Várzea
c - Igapó (LOW LAND)
1.1.1.2 - Atlantic
1.1.1.3 - Palm dominated

1.2 - Mixed
1.2.1 - Mountain
1.2.1.1 - Without Araucaria
1.2.1.2 - With Araucaria
1.2.2 - Gallery
1.2.3 - Swamp
1.3 - Seasonal
1.3.1 - Deciduous, Spiny (CAATINGA)
1.3.2 - Semideciduous, Sclerophyllous (CERRADÃO)
1.3.3 - Mixed, Semideciduous to deciduous (MATA SÊCA)

2.0 - Cerrado

2.1 - Seasonal, Sclerophyllous
2.1.1 - Cerrado
2.1.2 - Campo Limpo

3.0 - Campos of:

3.1 - Mountains
3.2 - Swamps
3.3 - Gallery
3.4 - Coastal Dunes

the land potentiality. On combination with other socio-economic factors, knowledge of land potentiality will enable authorities to establish well planned programs.

Public service agencies can, with this knowledge, investigate whether or not land is being used most efficiently.

Investment and development organizations can establish priorities and a credit system based on the knowledge of how to best use the land.

We have thus demonstrated the capacity of LANDSAT-1's multispectral scanner in providing the basic information necessary to develop a Brazilian natural resources program.

2. HYDRO/OCEANOGRAPHICAL PROCESS OF THE PATOS LAGOON FROM DATA OBTAINED BY LANDSAT-1 AND SKYLAB

2.1 - Objective

The study of hydro/oceanographical dynamic processes of coastal and lagunar waters using the multispectral images produced by orbital platforms.

2.2 - Area Justification

From the viewpoint of the remote sensing techniques application, this area constitutes an excellent laboratory by the presence of great contingents of suspended materials which could be detected and interpreted as the designers of the surface waters circulation trends.

The economic reason is based on the inability of the classical research methods to create a synoptical chart of the hydrological occurrencies of vast regions, causing high costs and inaccuracy in the spatial distribution of the values. The great port, agricultural and fishing activities justify completely the urgent and synoptical knowledge of the sazonal circulation models by their importance in the determination of erosion processes, transport and deposition of the sediment transported in suspension by the waters.

2.3 - Methodology

The method of analysis consist of several phases which were analyzed including the potentialities of each technique in function of the electromagnetic radiation interation with the atmosphere, the water and suspended materials, through:

a. Visual interpretation of the LANDSAT-1 MSS images and of the S-190-A of the SKYLAB, determining the convergence zones identified through different contrasts caused by different concentrations of suspended materials. From this it was inferred the surface circulation trends using ground truth data acquired in the field as for instance wind, tide, rain, debit, etc..

b. Semi-automatic techniques application as a justification of established

patterns in the starting phase (visual) using computer compatible tapes (filtration) and transparencies (density slicing and/or color enhancement).

c. Correlation of previous stages results with bathymetric charts, profiles, synoptic surface charts and mathematic models.

d. Determination of a set of images which characterizes the representatives sazonal events trying the justification of circulation models in function of variables.

e. Classification of the sediments deposition using considered models and granulometric analysis of the bottom sediments.

f. Comparison of the systems and the attempt of spectral identification of the different concentrations of suspended materials using geochemical analysis and radiometric survey simultaneous to images obtainment.

2.4 - Obtained Results

a. Two circulation models for the Patos Lagoon were obtained using LANDSAT-1 images. It is perfectly possible to analyse, considering the two events, the distinct conditions caused by the water surface in the different environmental conditions.

b. A circulation model was obtained through the photographic images of the SKYLAB (SL-3) which justify an hourly celular circulation determined by winds of weak intensity, during the satellite passage.

2.5 - Utility

The pre-existent knowledge of the surface circulation waters of the Patos Lagoon, presented by Patric Delaney (1962), demonstrates that the contribution of this new approach is of precious value when compared with thematic maps of circulation trends of this same author and of the series observed by the LANDSAT-1 and the SKYLAB (SL-3).

3. MAPPING OF GEOLOGICAL STRUCTURES USING THE LANDSAT-1 IMAGES

3.1 - Introduction

The possibility of visualizing great geological groups (structural/lithological) as a whole was impossible till some time ago. In a vast area as the Brazilian territory (more than 8,000,000 Km^2) it is possible to foresee the difficulties found by the reserchers to realize works in a regional scale and offering secure results. This is the reason why our small scale geological maps could not present enough structural information for a good geological study of a certain area.

Attempting to contribute to this special problem, INPE, as the divulger of new remote sensing techniques, and responsible for the Brazilian LANDSAT images studies, proposed to make regional maps emphasizing more geological structures studies.

A Project named "Project Structure" was delineated, consisting of mapping all the geological structures, using especially LANDSAT-1 images and other sensors as those of SKYLAB, radar, and, when necessary, aerial photographs. The maps will form charts to the millionth scale, following the international geographical division.

This project is presently in rapid development and it is planned, still for this year, a publication of five charts to the millionth scale.

3.2 - Objective

The main objective is to interpret and map geological structures as: faults, fractures, folds, linear features, circular structures and great stratigraphic units, through the systematic use of orbital images and other data.

In a further phase, to delineate, based on the distribution of mineral occurrences and structural analysis, areas with some mineral potential that could indicate new natural deposit of ores.

3.3 - Test Site

The South-Central Brazilian region is one which presents the best geological knowledge, offers bibliographical facilities, and, due to its great development, presents easy access to different regions. These factors are really important in the selection of this area, besides other ones as:

- good set of LANDSAT images, without cloud cover or other problems. Repetitive passages of the satellite during different seasons of the year.

- Variety of geological and structural features, showing a stratigraphic column embracing all the geological epochs.

- presence of some structural and stratigraphic problems whose regional analysis, through the LANDSAT-1 images, could be solved.

3.4 - Methodology

As a base for mapping, LANDSAT-1 images were used on the scale of 1:1,000,000, supported by other remote sensing products (SKYLAB mission and radar semi-controlled mosaics).

The systematic of the methods of works consists of:

a. Detailed mapping of the drainage system and other features in an overlay (for each image) then mounting an overlay mosaic which will form a planimetric base for the maps. For the preparation of this mosaic the transferring of image coordinates to the UTM system was necessary. Astronomic (or geodesic) points, already known, were used as control points, plotting them on the images. The result of this methodology enables the preparation of charts to the millionth scale with good relationship with the existent ones.

b. Later, mosaics were prepared using the LANDSAT-1 images in channels 5 and 7, over which was done a preliminar geologic interpretation parallelly comparing the results with the images in channels 4 and 6.

c. Using this preliminar geologic interpretation the explained elements were compared with a volume of data obtained by bibliographic analysis. The identification of these elements is so established, and related to formations, when possible, establishing a chronological order, This geologic map will furnish the base for a more correct structural interpretation, besides showing what the images could furnish about rocks, contacts, tone anomalies, etc.

d. In the fourth phase the final interpretation of the structures was realized. It was mapped as structural features all the ones possible to have geological meaning, identifying as linear features, those ones that presented some doubts as to their identification. Combining the geologic map and the structures outline, this final map will be composed by the representation of all the structures over a base settled in the division of great geological units, and whose legend makes possible the introduction to a tectonic map. It should be noted the distribution of the main known mineral occurrences aiming to delimitate areas with possible economic interest and that need to be studied with more details. Field work will be done only in the areas with problems or where the interpretation and analysis shows doubts or were defficient.

3.5 - Results

In the three composed maps (planimetric, geological and structural) much information could be discussed, some ones reformulating already existent works and others really pioneer.

In the planimetric map, the main objective attained was the excellent transference obtained from the coordinated system. From the result of this map the methodology to compose the mosaic for the other two maps was determined. The drainage and road systems, city locations, etc. were highly perfect, bringing corrections to many important water courses, new road systems, increasing greatly the existent information in works of compatible scale.

The stratigraphic units, previously known, were all mapped agreeing with previous work already done enabling better knowledge of areas considered doubtful or where little work was done. New ideas appeared referring to some formations.

As it was expected the map which brought more information to the geology of the area was the one which gave more emphasis to the structures. A great number of fractures, faults was mapped putting in check those ones photointerpreted by several researchers. The main directions were easily defined, their small or great frequency, associated to the different groups of rocks, making possible a division of the tectonic areas, differently affected.