

**SATELLITE IMAGE MAPS - AN ALTERNATIVE TO THE
SYSTEMATIC MAPPING IN BRAZIL**

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ABSTRACT

The aim of this paper is to present the situation of systematic mapping in Brazil, and to describe the methodologies used to produce image maps at INPE - The Brazilian Institute for Space Research, from primary data acquisition to the printing of final products. It also shows the state of cartographic production and updating of existing maps in the last two decades, emphasizing the potential of the use of satellite image maps as a complement to the conventional systematic mapping.

1. INTRODUCTION

The Cartography Commission - COCAR, created under Federal Law number 243 on February 28, 1967, came up from the evidence that the cartographic activities developed individually by several federal or state, public or private organisms at that time required a high level coordination, taking the aim and basis to a national cartographic policy joined to the necessity of the security and development of the country. Such policy should primarily benefit the systematic cartography activities, as this kind of cartography allows the establishment of a basic cartographic structure under which all different kinds of mapping are sustained.

In 1978, a dynamic cartography program was implemented with the purpose of preparing a systematic mapping of the whole national territory as well as reaching a cartographic production level compatible with the international necessities and commitments of the naval and air navigation.

In spite of the difficulties to accomplish and implement such a program, it brought a significant progress to the mapping of the national territory, proven by the fact that until 1977 only 44% of it was mapped, while in 1985 83% was already mapped, in an average of almost 5% each year. The previous years would not even reach the average of 3% of all the mapped area. In the COCAR working group there are federal organisms which execute the cartographic activities turned to the edition of topographic, thematic or special maps.

The dynamic cartography program brought direct benefits to the systematic cartography and to all other activities related to the cartography which need a basic groundwork to their services. Therefore, it was felt the necessity to elaborate a national cartographic plan which could determine the objectives concerning the thematic, special and systematic mapping turned to the social and economical development of Brazil.

From 1987 on the COCAR executive office decided to assume definitely the responsibility of activating the process to elaborate a national cartographic plan, where the main characteristics shall be the attempt to reach a consensus among the organisms which represent COCAR. This plan shall be spread to the cartographic community in general and to all cartographical users.

2. A DESCRIPTION OF TOPOGRAPHIC MAPPING SITUATION IN BRAZIL

The production of topographic maps in Brazil begun due to the efforts of Commission of Imperium General Chart (1873), followed by the Commission of Republic General Chart (1903) and latter by the Army Geographic Service (1917) - nowadays entitled Directory of Geographic Service (DSG) - and Brazilian Institute of Geography and Statistics (IBGE) (1940).

Such efforts were intensified by means of two basic facts: the American Air Force, during the second half of the 1960's, carried an aerophotogrammetric coverage of most of the Brazilian territory, and the dynamic cartography program pushed on the country mapping works in a faster way. The situation in the national territory concerning the mapped area until december, 1987 is presented in the table below:

SCALE	MAPPED AREA		AREA NOT MAPPED		TOTAL NUMBER OF SHEET
	NUMBER OF SHEET	PERCENTAGE	NUMBER OF SHEET	PERCENTAGE	
1:500,000	91	57,6	71	42,4	162
1:250,000	382	68,6	175	31,4	557
1:100,000	2040	66,9	1010	33,1	3050
1:50,000	1540	13,1	10222	86,9	11762
1:25,000	2000	4,3	44250	95,7	46250

Table 1 - Topographic Mapping Situation

It can be concluded from this table that Brazil does not have the minimum necessary knowledge (mapping in the scale 1:250,000) about the geographical aspects of approximately 30% of its territory (2.8 million of km²). In this case, the Amazonic region (in the Northern part of Brazil) is considered to be the place where less geographic data is found. Concerning the bigger scales, a number of approximately 35% of the territory is not mapped yet in the scale of 1:100,000 mainly in the northern part of Brazil. 85% of the territory is not mapped in the scale of 1:50,000.

It is not necessary to execute a 1:50,000 scale mapping in the most part of the Brazilian territory because of the geographical characteristics of the country and the way it was populated. Considering the occupation rate and the development of each region the problem is to update the existing maps, considering a previous scale selection.

Referring to map revision, it can be observed that most of the maps produced in the scale of 1:100,000 or smaller were obtained from old flights of more than twenty years ago, some of them over thirty years. There is not a systematic activity in the cartographic organisms to update maps. Another difficulty related to the topographic mapping is the selection of suitable scales to represent the national territory in its several regions.

The National Cartographic Policy tends to adopt the following basic directions:

- A permanent mapping program in the scale 1:1,000,000 edited every 10 years.
- A permanent mapping program in the scale 1:250,000 edited in a period of 10 year or less.
- A permanent mapping program in the scale 1:100,000 with editions in periods whenever an occupation process change is observed. At first, the Northern and Middle-west regions of Brazil (approximately 60% of the National Territory) must be mapped in this scale.
- A permanent mapping program in the scale 1:50,000, with editions in periods whenever an occupation process change is observed. Southern, South-eastern and North-eastern regions must be mapped in this scale (about 40% of the National Territory).
- An episodic mapping in the scale 1:25,000 focused on the metropolitan regions, very important to the specific plans, and regions where there are cities with more than 250,000 inhabitants (approximately 40 cities)
- A systematic program to update maps by means of a selected criterion based on the flight date, and also based on the evolution on the geographical aspects of each area.

Such programs are meant to bring the country a complete and up-to-date basic cartographic structure which can serve the needs of the social and economic development of the country.

3. SATELLITE IMAGE VIABILITY AS CARTOGRAPHIC BASIS

Due to the cartographic coverage situation and to the perspectives imposed by the directrices of the National Cartographical Plan, it can be observed that a great volume of work would be necessary to guarantee the complete coverage of the Brazilian territory as well as to maintain this coverage up-to-date. But the lack of resources, the difficulties to access certain regions and the unfavorable climate conditions together with the large territory to be mapped are the main facts which demand selective, progressive and coordinated actions according to a national middle and long term plan.

The mapping activity which beforehand just worked with the size of the covered area, today is directed aiming the most complete information able to represent the physical and social reality. This new phase in the cartography points to a mapping process using satellite images.

The satellite images are an excellent alternative for the Brazilian case. The advantages are a larger covering area, a continuous updating and lower costs. However, some factors establish restrictions in the usage of the images as basis for systematic mapping: the limitation imposed by the spatial resolution and by the geometric internal error (table 2), the impossibility to obtain altimetric information (with exception of the SPOT satellite) and the existence of regions with constant cloud cover.

Because of these factors, the orbital data usage to cartographic objectives does not substitute the application of the aerial photographic images; meanwhile, due to the advantages presented, it is a very important instrument to the mapping works as well as in the systematic map updating. This map updating with satellite images can be used to detect the level at which a map is outdated and also as a basis to the updating itself.

However, successive advancements experimented in the Orbital Remote Sensing engineering and technics provided a way for new researches in order to make possible the color reproduction of cartographic documents to enhance the most notable cartographic elements such as: drainage systems, roads, railways and city boundaries. These searches involve visual analysis techniques, digital treatment and graphical reproduction.

The visual analysis is necessary to define the color composite to be adopted. The digital treatment not only allows the radiometric and geometric corrections as well as it allows the usage of the algorithms to enhance some characteristics in the scene. The photographic treatment is directed to eliminate the possible radiometric discrepancies among the three photographic originals which will be used in the graphic reproduction,

trying to guarantee a perfect color balance and contrast. The graphic reproduction must avoid the loss of visual and texture quality of the scene, when turning the product from film to paper by the printing process, in continuous or semi continuous tones. Table 2 presents the results of the geometric evaluations of the scenes generated by INPE associating the suitable scales concerning the cartographic standards.

SENSOR	SPATIAL RESOLUTION (M)	GEOMETRIC PRECISION (M)	SUITABLE SCALE	PLANIMETRICAL STANDARDS (M)
MSS-LANDSAT	80	80 TO 120	1: 250,000	125
TM-LANDSAT	30	40 TO 50	1: 100,000	50
HRV-SPOT N2 MULTISPECTRAL	20	* 25 UP TO 40	1: 100,000	50
HRV-SPOT N2 PANCHROMATIC	10	* 15 UP TO 20	1: 50,000	25

* EXPECTED VALUES

Table 2 - Geometric Evaluation versus topographic map scales

4 - BRAZILIAN MODEL OF IMAGE MAP

In the early 80's INPE and DSG signed a contract for the development of researches attempting to generate a new cartographic product in Brazil: the image map. The common interest between these institutions was to give aid to an increasing number of requests by the part of the user community of cartographic products, as well as to investigate the possibility of mapping regions where the access is difficult, as also the unfavorable climate conditions which make impossible a perfect aerophotogrammetric coverage.

At this time, the researches were focused on the applicability of the MSS - LANDSAT sensor for mapping in the scale of 1:250,000. DSG made an option to use just two spectral bands (band 5 to enhance the urban limits and railways and band 7 for the drainage network). In fact, the main function of these scenes was to update the planimetric information. Following this methodology the image maps produced were: Rio Branco, sheet SC-19-X-C (1982), Campo Grande, sheet SF-21-X-B (1982), Cristino Castro, sheet SC-23-X-A (1983), and Florianópolis, sheet SG-22-Z-D (1984).

The results of these first image maps were not satisfactory enough to the cartographic users community. The main problems were the idea of preserving the characteristics of a drawn-map, and the phase of graphic reproduction, where the loss in the visual quality was very evident.

However, these efforts were responsible for a very representative progress between the publication of the first image map (Rio Branco, 1982) and the fourth image map (Florianópolis, 1984).

With the launching of Landsat 4, equipped with a new sensor, the Thematic Mapper (TM), researches were concentrated in the preparation of a product to emphasize the information in the scene. The 5,4,3 (RGB) color composite was chosen after testing twenty different ones.

As river traces, roads, and urban limits shall be naturally enhanced through digital processing, they were not printed over the color composite, as well as the toponymy. In 1986, the following image maps were edited: Campina do Norte, sheet SB-19-V-A-III, Benjamim Constant, sheet SB-19-V-B-I, Santiago, sheet SH-21-X-D and Vilhena, sheet SD-20-X-B.

Since 1987 COCAR has been coordinating a working group to deal with these image maps. The objectives of the group were concentrated on researches about the selection of the necessary bands for the color composite, and about graphic reproduction as an alternative to semi-tone and continuous tone printing processes. Investigations about digital data treatment were conducted looking for image enhancements and noise elimination. Figure 1 shows the image map generation process flow.

The first result obtained by the group was the edition of the image Barbacena, sheet SF-23-X-C, in 1987, using a 5,3,2 TM color composite. This image map brought a very representative advancement to the other maps already printed. The image map Lavras, sheet SF-23-X-C-1, will be edited this year, using a TM 5,4,2 color composite.

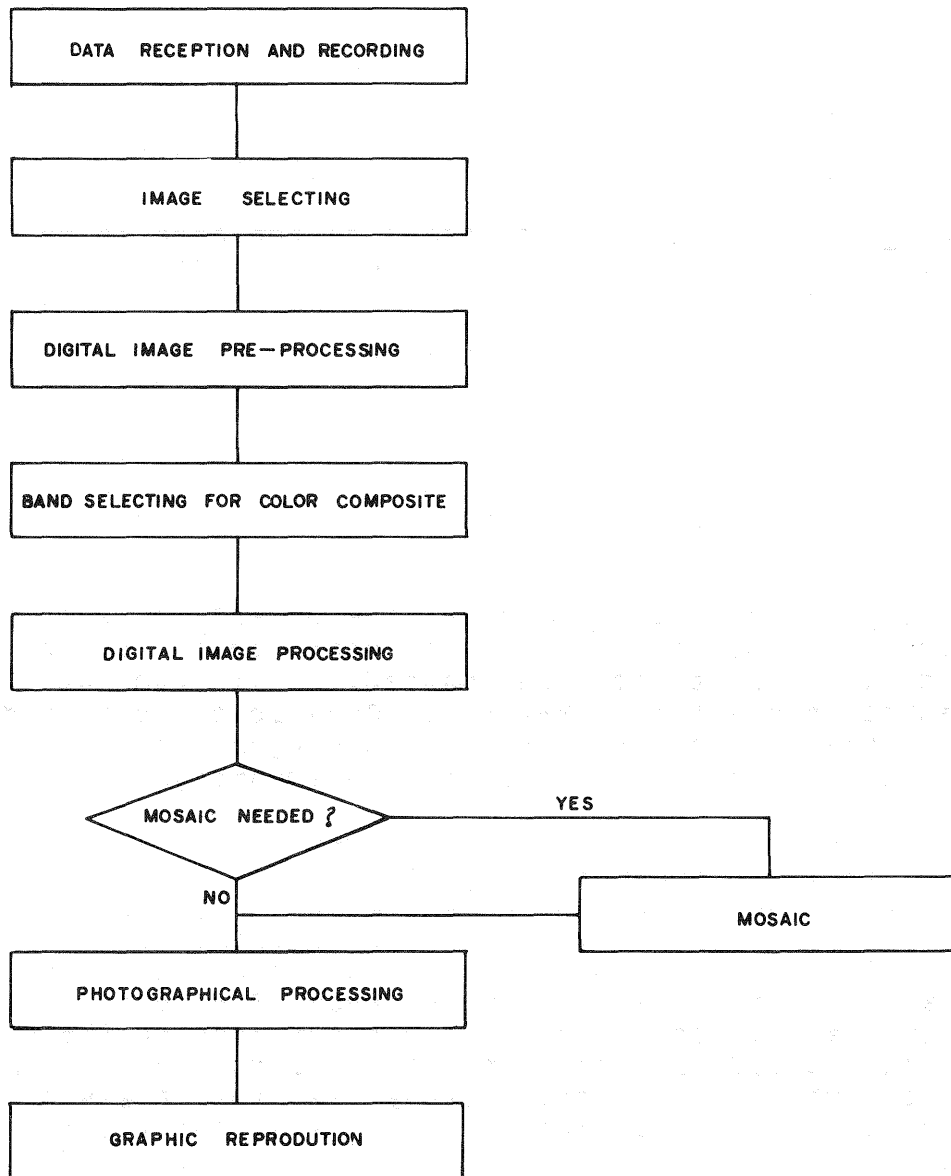


Figure 1: Image Map Generation Flow.

Data Reception and Recording: INPE has been receiving and recording daily LANDSAT and SPOT images, which are acquired within the range of its antenna installed in Cuiabá, Mato Grosso state. This reception station allows full coverage of Brazil and most of South America. Tapes recorded at Cuiabá are shipped to Cachoeira Paulista, São Paulo state, where the processing laboratories convert them into photographic final products, or computer compatible tapes (CCTs).

Image Selection: It is carried regarding the area to be mapped, as for the maps in scales 1:250,000 or bigger, one or two scenes of adjacent orbits are necessary for full coverage. This is viable due to the possibility of along track shifting the images in relation to the WRS grid. The search is done concerning the date, the cloud covering and the data quality.

Digital Image Pre-Processing: In this phase, system radiometric and geometric corrections are executed. If a mosaic is needed, both scenes are corrected according to the same orientation of the UTM grid.

Band Selecting for color composite: The objective is to select, among several possibilities, the best color composite to represent the area to be mapped. It can be used a multispectral projector MSP-4 from Carl Zeiss Jena, a digital display Comtal Vision-One, or even photographic films, where the bands are associated to the three elementary colors.

Digital Processing: It is generally aimed to the application of spatial filters to enhance some characteristics of the image, or even the scene as a whole, and also to the application of spectral rotation algorithms: principal components and IHS--RGB transformations. The IHS--RGB transformation is being used as a tool which enables a perfect balance of colors (working in the hue and saturation components) without losing the contrast quality (reinforced by the intensity component). Another application which is under study is the register among multispectral scenes, as for example: multispectral bands of TM-LANDSAT or HRV-SPOT with the panchromatic band of the HRV-SPOT sensor.

Mosaic: This step is responsible for the combination of two adjacent corrected images covering a region of $1.5\sigma \times 1.0\sigma$ corresponding to a map in the scale of 1:250,000. The displacement error between the scenes is observed through a visual appliance, when the overlapping region of the scenes is defined. The histograms of this region will be used to equalize radiometrically the scenes. Besides, corresponding pixels with least differences between gray levels are chosen, spreading this difference in the neighborhood around them. This procedure tends to diminish the radiometric difference between the adjacent images, as well as to disguise the mosaic line.

Graphic reproduction: After the processing of the three photographic originals in black and white films, the cartographic bases are elaborated in the final scale of the image map presentation. At this phase, a computer controlled Laser sweeping device (CP 340 Hell Scanner Plotter) is used. Latter, the color test, the preparation of the printing plate, and the offset printing in semitone are carried.

5 - CONCLUSION

Brazil presents several areas with shortage of Cartographic covering. Besides, there is a very high level of mapped areas but yet not updated. As the researches for the usage of satellite images in colour paper were developed, the image map came up as an alternative cartographic product in order to enable the execution of the National Cartographic Plan.

These researches enlarge the combined participation of experts in digital and photographic treatments, graphic reproduction and photo-interpretation. In these phases, it is necessary to control all the variables which can contribute to undervalue the image map visual quality.

The image map working group efforts are laudable, as it is very important to Brazil to reach the state of art

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