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collection, management and dissemination**

### **Activities and experiences of Brazil in the field of cartography\*\***

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## Activities and Experiences of Brazil in the field of Cartography

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### ABSTRACT

This paper presents a review of the activities and experiences of the Brazilian Institute of Geography and Statistics (IBGE) in the field of Cartography, as well as the expectations for the coming years. In especial, the geodetic, cartographic, and thematic mapping activities, as well as those related to the construction of the National Spatial Data Infrastructure (INDE) are described.

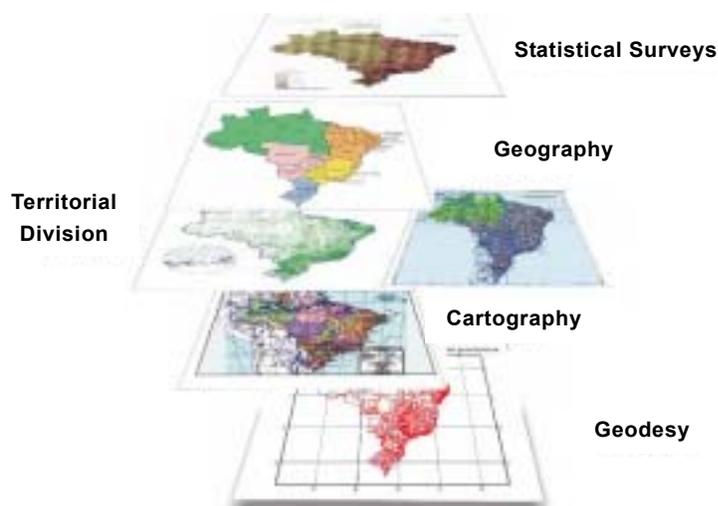
### INTRODUCTION

With the mission of portraying Brazil through information necessary to the knowledge of its reality and the exercise of citizenship, the Brazilian Institute of Geography and Statistics (IBGE) is responsible for the production, analysis and dissemination of statistical data (in demographic, economical and social fields) and geoscientific information (geodetic, cartographic, geographic and related to natural resources and to the environment). Dealing in the same institution with activities concerning both the statistical and geoscientific fields facilitates data integration aiming at the establishment of a reliable database associated with a homogeneous and consistent territorial structure. Figure 1 shows a sketch of the layers of information produced by IBGE.

The duties of the Institute in the field of Cartography are the following: (IBGE, 2004):

- Regulator and coordinator of the Brazilian Geodetic System (SGB), in order to guarantee geodetic reference to planimetric and altimetric positioning all over the Brazilian territory;
- Regulator and coordinator/producer of the geographic mapping of Brazil at 1:2,500,000 and smaller scales, supplying the production of atlases and other maps; at 1:1,000,000 scale (the International Chart of the World to the Millionth), supporting multiple uses related to a nationwide vision (map production and geospatial analyses at regional and state levels) as well as the compilation of basic information for the Global Mapping Project;
- Disseminator and producer, together with the Geographic Service Directorate of the Army, and other institutions belonging to the National Cartographic System, of the Brazilian systematic topographic mapping, at 1:250,000, 1:100,000, 1:50,000 and 1:25,000 scales, supplying the country with digital

topographic charts and preliminary products such as aerial photographs referenced to SGB, orthorectified satellite images, orthophoto charts, image maps, etc;



**Figure 1: Layers of information produced by IBGE**

- Map producer of political-administrative units (at state, municipal and intra-municipal levels) and of census sectors, for planning, data collection and release of statistical data; this information constitute the territorial base for monitoring of the political-administrative division of the country, which is used in several statistical surveys (demographic census, agricultural census, National Household Sample Survey, among others).

The nature of the information produced by the Institute explains its potential in terms of contributing to the National Spatial Data Infrastructure (INDE). This task is now being structured under the supervision of

the National Cartography Commission (CONCAR), a commission coordinated by the Ministry of Planning. It is IBGE's duty to supply technical and administrative support to CONCAR and to its Executive Secretariat (CONCAR, 2005).

This paper describes the activities and experiences of IBGE in the field of Cartography, as well the expectations for the coming years.

## GEODETIC ACTIVITIES

With respect to its responsibility of establishing and maintaining SGB, IBGE has, for more than 60 years, released reference data for positioning over the national territory. Currently, the activities are focused on the establishment and operation of active geodetic networks (Brazilian Network for Continuous Monitoring of GPS – RBMC - and Geodetic Permanent Tide Gauge Network – RMPG), on the establishment and maintenance of passive networks (State GPS Networks and SBG High Precision Altimetric Network), in addition to the densification of gravimetric data applied to the determination of height values.

### Brazilian Network for Continuous Monitoring of GPS (RBMC)

The Brazilian Network for Continuous Monitoring of GPS (RBMC) is an active geodetic network whose stations have GPS receivers collecting data twenty-four hours a day, seven days a week. These data support coordinates determination of any point of the territory using GPS (Global Positioning System).

IBGE started establishing RBMC at the end of 1996 with the support of the National Fund for the Environment (FNMA) and of the Polytechnic School of the University of São Paulo.(EPUSP). Currently, RBMC is composed of 19 stations (Figure 2) distributed across the national territory. The stations are automatically monitored and controlled by the control center located in Rio de Janeiro. The data collected by each station of the network are normally released through IBGE's website within twenty-four hours after the observation session, being available to all users free of charge.

A project related to network modernization is currently being developed in order to implement a real-time capability to the network. This feature will allow the computation of WADGPS (Wide Area Differential GPS) corrections, expected to be transmitted by satellite to users in Brazil and surrounding areas, supporting a variety of static and cinematic applications (navigation).



**Figure 2- RBMC stations in operation, being tested and to be established**

**State GPS Networks**

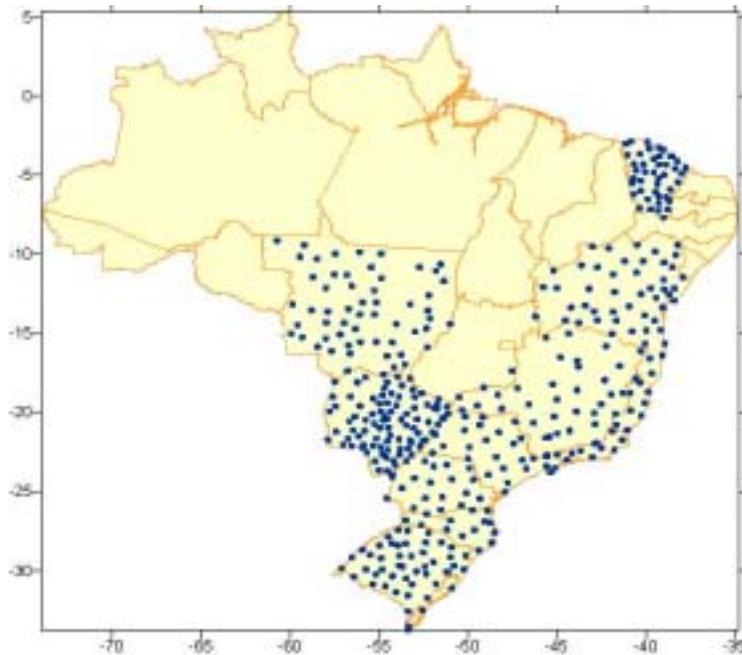
The establishment of state GPS networks is intended to supply the Federative Units with highly accurate geodetic networks which can be easily maintained and which can serve as reference structure to any positioning applications based on classical methods (for topography) or on GPS. A guarantee of their physical integrity is the main feature of the stations composing these networks. Thus, they are located in areas selected together with the representation of state communities, preferably in public institution facilities. So far, networks have been established in eleven states: Bahia, Ceará, Espírito Santo,

Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, and São Paulo (Figure 3). The establishment of state networks in the Northeast region is expected to occur in 2005.

**Geodetic Permanent Tide Gauge Network (RMPG)**

The Geodetic Permanent Tide Gauge Network (RMPG) is the second active network operated by IBGE. It was established with the objective of monitoring the evolution of several SGB vertical reference systems. The tide gauge stations that compose the network measure sea level, collecting data twenty-four hours a day, seven days a week.

The collected data will allow the determination of mean sea level along the Brazilian coast and its correlation with past observations. Besides, the network will support the determination of correlation between all remaining vertical reference systems, especially those used in Nautical Charts and in seaport operations. By this way, engineers and scientists will be able to unify the height systems used in their engineering projects, in the production of maps and charts of the national territory and in scientific coastal studies.



**Figure 3: State GPS Networks**



**Figure 4: High Precision Altimetric Network and Geodetic Permanent Tide Gauge Network**

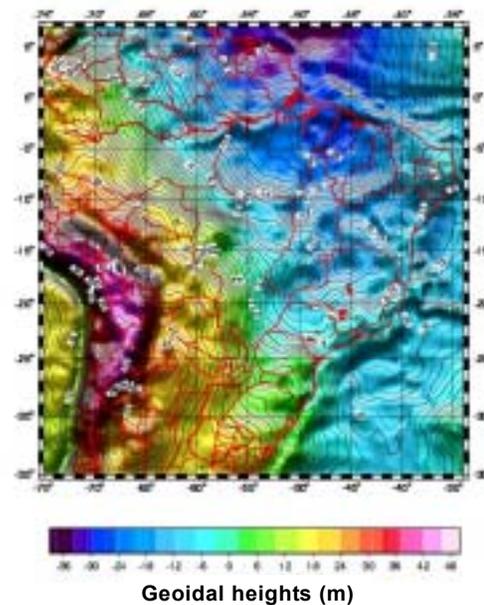
Three stations are already in operation: Macaé (RJ) with observations since 1994, Imbituba (SC), since 1998 – both improved in 2001, through the installation of new digital equipment –, and Salvador (BA), installed at the end of 2002 and improved with a digital equipment in October 2004. The complete configuration of the network includes the establishment of three additional stations in Santana (AP), by June 2005, Belém (PA) and Fortaleza (CE) (Figure 4).

#### **Change of the Geodetic Reference System Project (PMRG)**

This project was created in October 2000 with the objective of promoting the adoption, in Brazil, of a new geodetic reference system, geocentric, modern and compatible with the state-of-the-art positioning technologies.

In this respect, the Geocentric Reference System for the Americas, in its realization of 2000 (SIRGAS2000), was officially adopted on February 25, 2005, as the new reference system for SGB and for the National Cartographic System (SCN), according to the recommendation of the Seventh United Nations Regional Cartographic Conference for the Americas. The documents on which this adoption is legally based are the Decree no. 5334/2005 (Presidency of the Republic, 2005), of January 06, 2005, which changed the text of the Regulating Instructions of the National Cartography Technical Standards (Decree no. 89817, of June 20, 1984 – Presidency of the Republic, 1984), and the Resolution n° 1/2005 of the President of IBGE (IBGE, 2005a), which established a 10-year transition period during which SIRGAS2000 can be used together with former reference systems (SAD 69 and Córrego Alegre).

At the beginning of the transition period, the coordinates of all GPS stations in the Geodetic Data Base were made available to users through a new user-friendly interface on the Internet (IBGE, 2005b). Besides, a new geoid model developed in partnership with the Polytechnic School of the University of São Paulo (Figure 5) was also released to users at the same occasion. In both cases, information is referred to SAD 69 and SIRGAS2000.



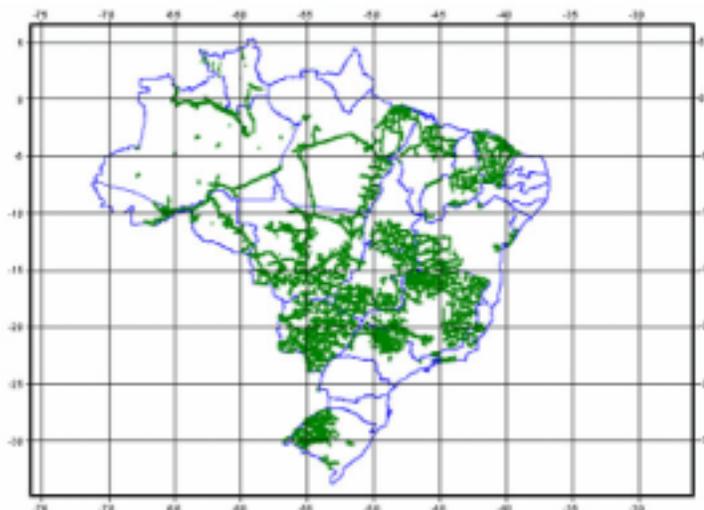
**Figure 5: Geoidal Map referred to SIRGAS2000**

#### **High Precision Altimetric Network (RAAP)**

The High Precision Altimetric Network is the vertical reference frame of SGB and it currently contains more than 65,000 altimetric stations (bench marks) spread all over the country along main roads and railroads, corresponding to more than 160,000 kilometers of two-way spirit leveling (Figure 4). The origin of the heights is the Imbituba Datum, defined through the average of the annual mean sea level values obtained between 1949 and 1957.

## Gravimetry

Gravimetric data are primarily important to the accurate determination of geoid-referred heights (i.e., related to mean sea level). Gravimetry has acquired a systematic character at IBGE since 1990, in order to fill large gaps of information on gravity acceleration in Brazil, especially in the North, Northeast and Central West regions. Since then, over 25.000 stations have been established (Figure 6).



**Figure 6: Gravimetric stations established since 1990**

## CARTOGRAPHIC ACTIVITIES

The financial resources for cartographic production at IBGE have been steadily reduced along the last decade, following a worldwide tendency. Due to this fact, the current available mapping, in several scales, is not updated in general, as most of the charts were produced between the 60's and the 80's. Besides, the country is only totally covered at 1:1,000,000 scale, with the existence of cartographic gaps at scales ranging from 1:250,000 to 1:25,000 (Figure 7). Table 1 lists the percentage of existing topographic sheets at scales used in the production of systematic mapping. Figure 8 shows the cartographic production by decade at 1:250,000, 1:100,000 and 1:50,000 scales, where the situation of outdated maps can be clearly seen.

**Table 1: Percentages of existing topographic sheets at scales used in systematic mapping**

SCALES	NUMBER OF	COMPLETE	MAPPING
1:25 000	47.712	492	1
1:50 000	11.928	1.647	14
1:100 000	3.049	2.269	75
1:250 000	666	444	81
1:500 000	154	68	37
1:1.000.000	46	46	100

Despite the mentioned budget limitations, the Institute has been successful in conducting projects on Cartography, among which the following must be mentioned: the conversion of analogical mapping into digital; the SP/MG/GO, SP and SC mapping; Bahia and Maranhão gaps mapping; Integrated Cartographic Digital Base of Brazil to the Millionth Scale (bCIMd),

with effects on the United Nations Global Mapping (ISCGM, 2005); municipal mapping supporting census operations; etc.

In order to improve the current mapping situation in Brazil, the Institute has conducted several studies towards using satellite images for map updating and production. The development of projects for mapping of the Maranhão and Bahia gaps, using SPOT4 images, is one of the consequences of such efforts. The possible availability of medium and high resolution satellite images obtained by optical sensors and radar at a more reasonable price has taken the Institute to strongly consider this alternative in the planning of future activities. The launching of the Japanese satellite ALOS (Advanced Land Observing Satellite – JAXA, 2005), expected to occur this coming September, together with the discussion by the Brazilian government about the installation of one or more orbital data reception antennas. reinforces these expectations.

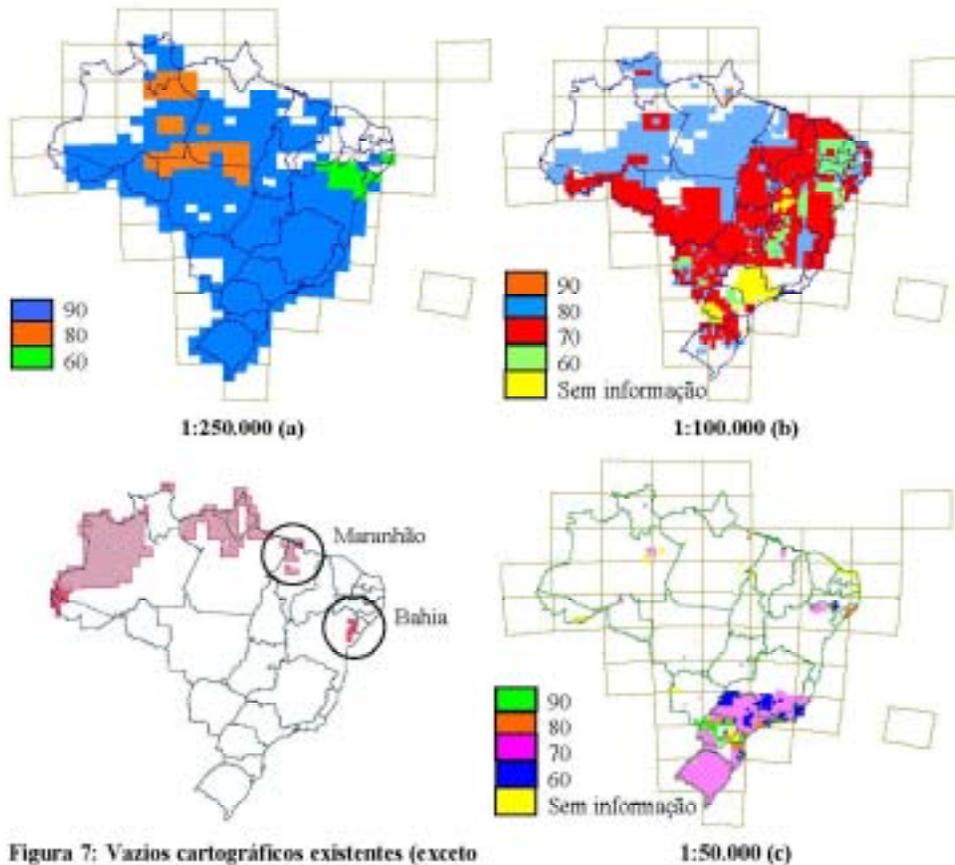


Figura 7: Vazios cartográficos existentes (exceto na escala de 1:1.000.000), com destaque para os estados da Bahia e Maranhão

Figura 8: Produção cartográfica por década para as escalas de 1:250.000 (a), 1:100.000 (b) e 1:50.000 (c)

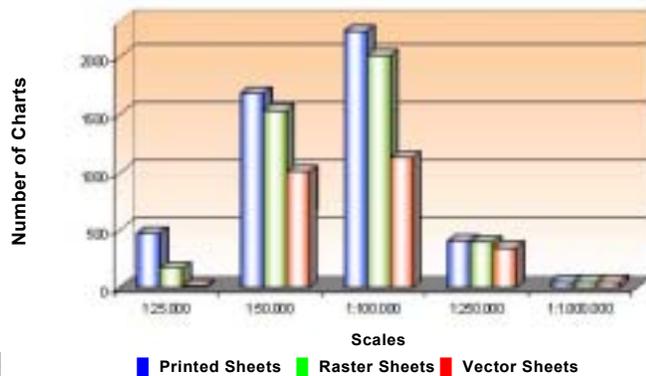
**Project of Conversion of Analogical Mapping into Digital Mapping**

At the beginning of the 90's, IBGE started a project related to mapping production modernization and automation. The purchase of equipment and software, added to staff training, led to the beginning of the conversion process of analogical into digital cartographic data. Almost all printed charts have already been converted into the raster format, whereas 50% of which are already in vector format (Figure 9).

**SP/MG/GO, SP and SC Mapping Projects**

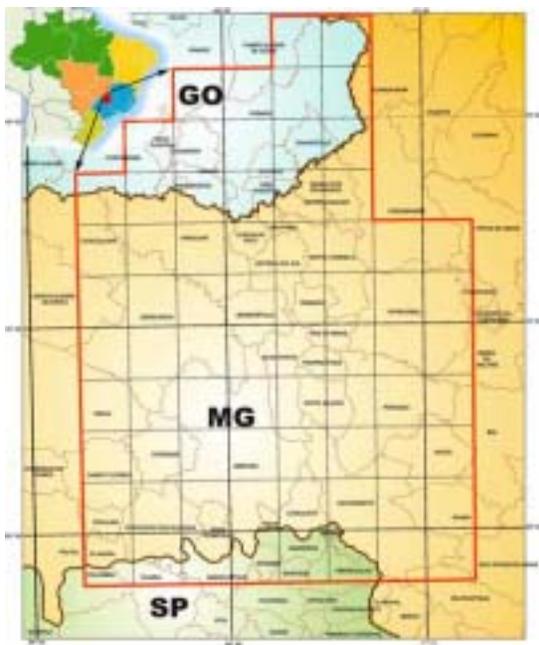
The SP/MG/GO aerial photogrammetry mapping project is expected to generate 73 topographic charts, at 1:50,000 scale and 38 ones at 1:25,000 scale, corresponding to a total area of 53473 km<sup>2</sup>, with 41601 km<sup>2</sup> in Minas Gerais (77.80%), 8922 km<sup>2</sup> in Goiás (16.68%) and 2950

**Project of Conversion of Topographic Mapping**



**Figure 9: Current situation of conversion of topographic mapping into digital media**

km<sup>2</sup> in São Paulo (5.52%). Aerial coverage was carried out in 2002, when 3403 aerial photographs at 1:35,000 scale along 56 strips were taken. The first digital topographic charts will be available to users in the middle of this year. Figure 10 shows the area covered by the project.



**Figure 10: Area covered by the SP/MG/GO mapping project**

In 2004, recent aerial photographs were acquired, partially covering the states of SP and SC. Based on this material 37 topographic charts at the 1:50,000 scale and 169 charts at 1:25,000 scale will be produced, covering an area of about 34,000 km<sup>2</sup> (94 municipalities). The previous cartographic maps, at 1:50,000 and 1:100,000 scales, were outdated for approximately thirty years, in a region of significant population growth in the period ( $\approx$  150%).

#### **Bahia Gap Mapping Project**

In this project, seven planimetric charts at 1:100,000 scale of the Bahia cartographic gap (see Figure 7), using 14 SPOT4 scenes and corresponding to 21,000 km<sup>2</sup>, will be generated. The digital charts will be available to the public by the end of this year.

#### **Maranhão Gap Mapping Project**

A total of 22 planimetric charts at 1:100,000 scale using 20 SPOT4 scenes, corresponding to 56650 km<sup>2</sup> of the mapping gap in Maranhão, will be generated in this project. The digital charts will start to be available to the public in 2006.

### **Integrated Cartographic Digital Base of Brazil to the Millionth Scale (bCIMd)**

The integrated digital base of the Brazilian territory at 1:1,000,000 scale has been available to the public since December 2004. A Program of Permanent Sharing of the bCIMd is being established in cooperation with several users who are also producers of the information contained in this base (for example, Transportation, Environment, and Indian Lands Ministries). The objective of the program is to maintain this base permanently updated. The development of this project supported Brazil's participation, through IBGE, in the United Nations Global Mapping Project. The Brazilian contribution to the project was delivered in June 2005 to the Secretary General of the International Steering Committee for Global Mapping (ISCGM, 2005).

### **Municipal Mapping Supporting Census Operations**

With the objective of supporting the statistical activities developed by the Institute, especially for demographic and agricultural censuses, the Cartographic branch generates municipal and intra-municipal maps. It also monitors the political-administrative division of the country and represents it through digital data sets, which, together with the census data sets, constitute the territorial base of the country. For the last census (2000), approximately 215000 maps of census sectors were generated, corresponding to more than 5500 municipalities. The updating process preceding the next agricultural census – expected to happen in 2007 – and for the 2010 demographic census has already begun.

## Geographic Mapping

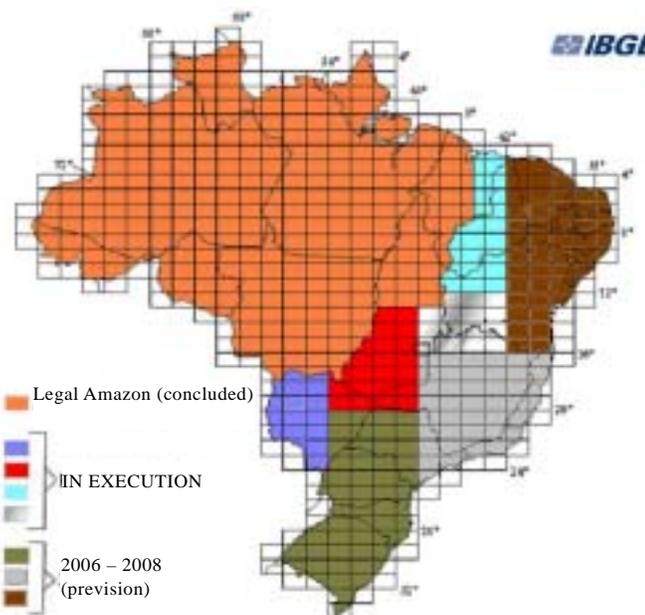
This segment of the cartographic production of the Institute covers the elaboration of maps of Brazil at 1:2,500,000 and smaller scales. The political-geographic map, at 1:5,000,000 scale, is currently in its second digital version, in which the geospatial elements have semantic data associated to them in a database. In 2005, a new version of the map of Brazil at 1:2,500,000 scale was published. The map provides information for the production of several atlases. In 2003, the Geographic Atlas for Students was published (in analogical version and in CD-ROM); it has been used in public and private junior and high schools in the country. In 2004, the National Atlas of Brazil in DVD was released, which is being simplified in order to increase its use by the public. In May 2005, the Institute released the My First Atlas publication, which is intended to provide teachers of Geography and elementary school students with material related to the field of Cartography.

## Geographic Names

This course of action was reestablished in 2005, with the approval of the project on Geographic Names of Brazil Database – BNGB, whose development is being conducted by a multidisciplinary working group. After analyzing the work developed by other countries, the group is conducting a conceptual and physical modeling of the aforementioned database. It must be pointed out that contact is being maintained with the Latin American Division on Geographic Names of the Pan-American Institute of Geography and History (PAIGH), in order to submit to PAIGH, in 2006, a proposal of a multilateral project with countries of South America on the topic.

## ACTIVITIES ON THEMATIC MAPPING

In order to fulfill its mission of providing basic information about the national territory, IBGE carries out permanent activities aimed at the identification, inventory and mapping of themes related to renewable and non-renewable natural resources, focusing on their occurrence, distribution, potential, availability, type and utilization degree, directed to systematic, sectorial or integrated knowledge, as well as the physical-biotic characterization of the Brazilian territory. This information production regarding the physical field (geology, geomorphology, soils) and biotic field (vegetation) of the country has, among other applications, the ability to provide basic information to the most diverse projects such as integrated projects of Ecological-Economic Zoning and Environmental Diagnosis. Some major products of these activities are thematic maps (geology, geomorphology, soils and vegetation). Besides these, hydric resource maps and others showing the coverage and use of the soil in several regions of the country are also produced. Figure 11 shows the situation of the natural resources mapping produced up to the present date and the planning for oncoming years. It can be seen in this figure that the Amazon region – representing around 61% of the national territory – is already completely mapped in the themes of geology, geomorphology, soils and vegetation. This was the result of the contract signed between IBGE and the Commission for Implementation of Aerial Space Control System (CISCEA)/System of Vigilance for the



**Figure 11: Natural resources maps (geology, geomorphology, soils and vegetation) produced and planned**

Amazon Project (SIVAM), developed from 1998 to 2004. The digital graphic files generated in the scope of this contract were organized according to the millionth chart subdivisions, with their elements compatible with 1:250,000 scale. This mapping was properly structured to be used in Geographic Information Systems (GIS).

#### **THE ESTABLISHMENT OF THE NATIONAL SPATIAL DATA INFRASTRUCTURE (INDE)**

The acknowledgment of the importance of planning and of territorial administration occurs in the three governmental levels. CONCAR (National Commission of Cartography) plays an essential role in promoting the means to achieve more efficiency and effectiveness of government actions through the integration of activities focused on the territory.

Since October 2003 the commission activities have been intensified, based on the functioning of its four sub-commissions: Legislation and Standards (SLN), Planning and Monitoring (SPA), Spatial Data Structuring (SDE) and Communication (SDI). The objective of SDE is to contribute to INDE development, promoting methodological and technological consistency and data and metadata structuring standardization in order to organize production, dissemination and use of cartographic information.

In March 2005, IBGE became one of the search tools of the Clearinghouse maintained by the Federal Geographic Data Committee (FGDC), making available around 3900 metadata of cartographic and thematic products of the Institute. It must be emphasized that the Metadata Committee was established in the SDE structure with the responsibility of implementing the National Spatial Metadata Database.

The strategic planning of CONCAR (CONCAR, 2005a) has been recently concluded. Its mission has been defined as to coordinate and guide the elaboration and the implementation of the National Cartographic Policy and the maintenance of the National Cartographic System (SCN), towards organizing the acquisition, production and dissemination of geospatial information to the Brazilian society. In terms of vision of future, it is expected that the commission becomes an entity recognized by society, able to assure a National Cartographic System of excellence which guarantees the integrity of an up-to-date National Spatial Data Infrastructure. As it can be seen, INDE is explicitly mentioned in the commission's vision of future, confirming the importance given to the theme.

In the development of INDE, it is of capital importance the effective participation of the member organizations of CONCAR in the implementation of an inventory of their existing cartographic bases, according to standards of metadata, with the objective of identifying gaps and of checking their quality and consistency. This inventory is the basic input to provide the integration and dissemination of geospatial bases financed by the Brazilian State, in order to enable the use of information systems to support decisions in various segments of government and private sectors. Another essential factor is the constitution of a spatial data sharing program, which is necessary to consolidate the existing geospatial bases, especially in digital and State scopes. Based on this premise, efforts are being made to establish a structure of mutual support among organizations and entities that perform SCN-related activities (source of the fundamental data of INDE), so that technical specifications and general standards inherent to state-of-the-art of the production and dissemination of digital cartography at cadastral, topographic and geographic scales can be established. It is also being planned, in the scope of CONCAR, to hold sectorial meetings with the objective of identifying the models of necessary geospatial data, its documentation, storage and dissemination, and also with the objective of deciding which fundamental data are needed for referencing the sectorial thematic mapping and which thematic data will be applied to common use. Regional meetings with Cartography and Planning State organizations are expected to take place in order to identify their interests related to topographic and cadastral mapping (CONCAR-SE, 2005).

## CONCLUSIONS

In this paper, activities carried out by IBGE in the field of Cartography have been presented. Despite all that has been done so far, the current situation is facing a steady reduction of the available financial resources, due to the transfer of funds allocated to basic cartographic activities in the past to other sectors (environmental issues, health, education, etc.) before the conclusion of the country mapping. This fact has caused difficulties in the implementation of activities related to land administration. In this respect, it is urgent to obtain resources to promote mapping update and production from programs and projects associated to other sectors, especially those benefited and financed by international agencies.

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