Geospatial tools and their use in Environmental Statistics

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ABSTRACT

IBGE – *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics) has a special characteristic as it includes in the same institution the missions of a National Statistical Office and of a National Geographical Office. This configuration gives to the institution an extraordinary comparative advantage in the production of environmental information, considering the possibility of intensively using geospatial tools in the production, analysis and dissemination of environmental statistics. The improvement that can be achieved generating Basic Statistics, Indicators and Accounting products using geospatial tools, especially those based on Geographic Information Systems – GIS, is presented in this paper. Using remote sensing to observe the phenomenon in the reality and to register it in an adequate way is also focused in here, through examples of using geospatial technologies to produce and analyze environmental information (deforestation, burnings and hot focus; genetic types and geological age of rocks; and stock and change account for Acre state land cover). A list of other IBGE products generated using the other methods of collecting data, as survey, administrative records and indirect estimation, is presented at the end of this paper.

INTRODUCTION

IBGE – *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics) has a special characteristic as it includes in the same institution the missions of a National Statistical Office and of a National Geographical Office. It is a Federal Government institution in Brazil responsible for producing, analyzing and disseminating statistical information (demographic, economic and social), as well as geodetic, cartographic, geographic, natural resources and environmental information. This configuration gives to the institution an extraordinary comparative advantage in the production of environmental information, considering the possibility of intensively using geospatial tools in the production, analysis and dissemination of environmental statistics.

There is a consensus that official statistics offices generate three types of products which deal with environmental information: Basic Statistics, Indicators and Accounting.

RADERMACHER (2008)[1], in recent meeting about Environmental Statistics and Climate Change, has presented the profile of these products: i) basic statistics have more empirical measurability and are closer to reality; ii) sets of indicators, in general, could have more political relevance, be more understandable by the police makers and can be more easily produced and iii) accounts have more theoretical consistence correlating the environmental information with the economy. The proposition of the initiative group of the working group on environmental statistics, approved in the eighth meeting of the Executive Committee of the Statistical Conference of the Americas of the Economic Commission for Latin America and the Caribbean, supports this conception, using the broad concept of environmental statistics which includes both environmental statistical series and environmental indicators and accounts. It is recommended that these three products be built up gradually and synergistically[2].

The improvement that can be achieved generating these products using geospatial tools, especially those based on Geographic Information Systems – GIS, is presented in this paper.

To produce any kind of statistic, it is particularly indispensable to observe the phenomenon in the reality and to register it in an adequate way. Statisticians, in general, can use four methods to carry out this task: a survey (or census); administrative records that are collected for other objectives but can be appropriated as statistics; indirect estimation or models relating existing data to technical coefficients; and remote sensing observations. This last method is focused in here, through the following examples of using geospatial technologies to produce and analyze environmental information:

- Environmental indicators related to deforestation, burnings and hot focus;
- Basic statistics related to rocks and their genetic types and geological age;
- Environmental accounts produced in physical terms, based on the stock and change account for Acre state land cover.

A list of other IBGE products generated using the other methods of collecting data, as survey, administrative records and indirect estimation, is presented at the end of this paper.

ENVIRONMENTAL INDICATORS

Burnings and Hot Focus

Based on satellite observations, INPE – *Instituto Nacional de Pesquisas Espaciais* (National Institute for Space Research) monitors the hot focus across the Brazilian territory

[1] RADERMACHER, W. *Environment ↔ Economy. Toolbox of Official Statistics*. Presentation in the Conference on “Climate Change and Official Statistics”. 14-16 April 2008,Oslo. Available in: <http://unstats.un.org/unsd/climate_change/docs/presentations/1430_Walter_Radermacher_session7.pdf> Accessed: January 2009.

[2] *Activities report of the initiative group of the working group on environmental statistics*. Santo Domingo, 2008. Available in: <http://www.eclac.cl/ceacepal/documentos/LCL2948i.pdf> . Accessed: January2009.

in a daily basis. This information is used by the national environment agency, IBAMA – *Instituto Brasileiro do Meio Ambiente e Recursos Naturais* (Brazilian Institute of the Environment and Natural Resources) to feed its program of preventing and controlling burnings. Figure 1 shows the density of hot focus in Brazil in 2006, revealing its main concentration along the border of the Amazon biome.

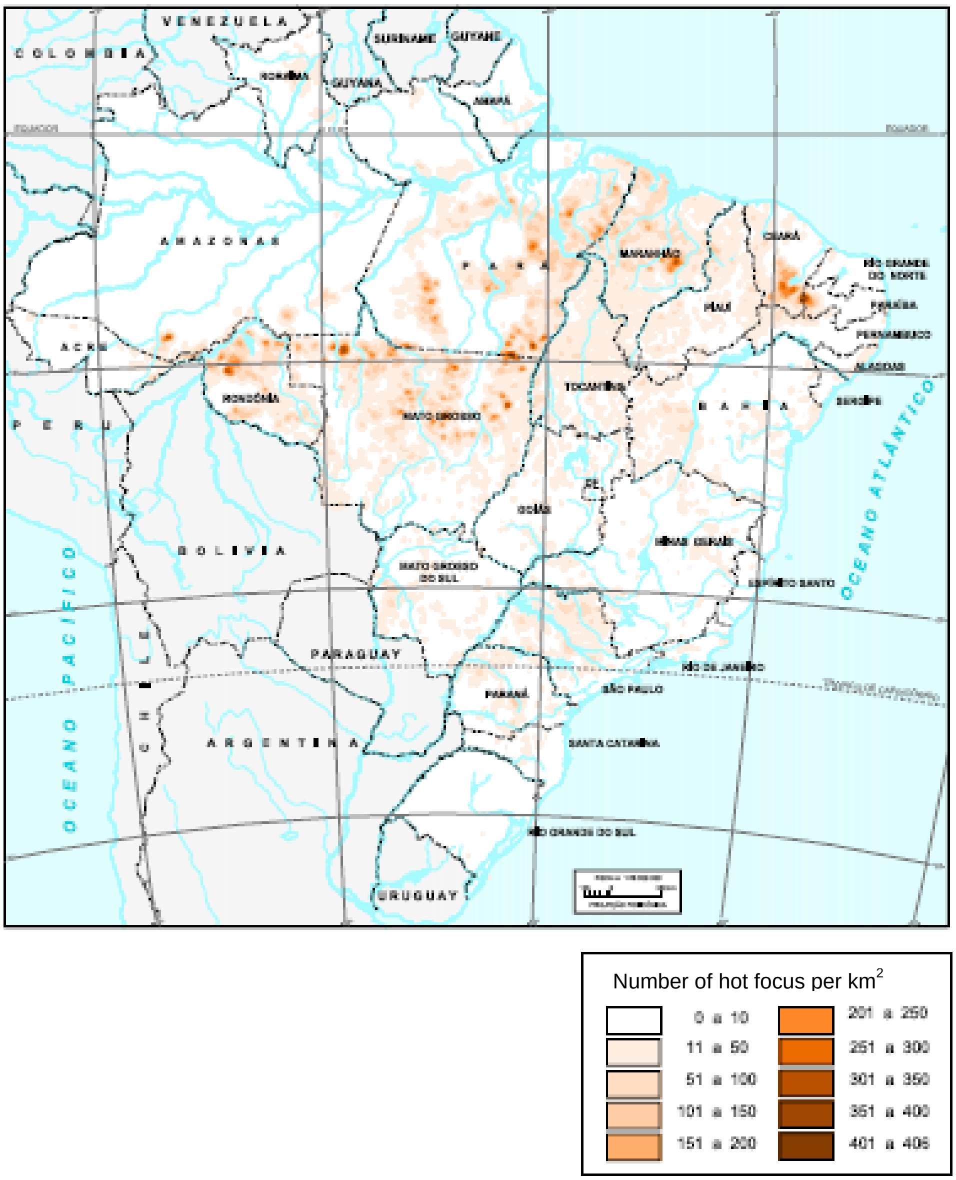

Figure 1 – Density of hot focus in Brazil – 2006

The data are accumulated along each year, and the result is used as an environmental indicator which can be very useful to identify critical regions and to support long term policies based on the tracking of the indicator's time series. Figure 2 presents the hot focus number in Brazil from 1998 to 2006, showing that the majority of occurrences happens in the Legal Amazon, with the highest values happening between 2002 and 2005. The Legal

Amazon is a region which has more than 5.2 million Km^2, corresponding to almost 60% of the Brazilian territory.

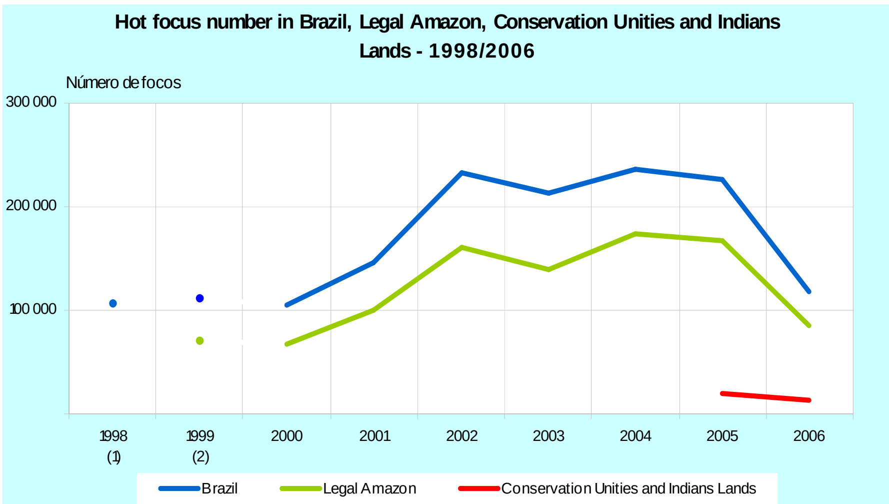

Figure 2 – Hot focus number in Brazil from 1998 to 2006

Legal Amazon deforestation

Due to its continental dimensions, it is not possible to measure the impacts of human actions in the Legal Amazon without using satellite imagery. The Brazilian government has two permanent systems to monitor the deforestation in this region. The first one, named DETER – *Sistema de Detecção de Desmatamentos em Tempo Real* (Real time Deforestation Detection System), by INPE, provides, since May 2004, monthly information about the state of deforestation and is used by authorities to direct short term corrective measures in order to stop those illegal actions. The other one, named PRODES – *Monitoramento da Floresta Amazônica Brasileira por Satélite* (Brazilian Amazon Forest Monitoring by Satellite), also by INPE, generates yearly estimates of this type of information with higher accuracy, eliminating, for example, shadows caused by clouds.
The PRODES data is used to inform the government and society about the deforestation stage and to plan long term actions. This information, i.e. the gross deforestation (Figure 3) and the estimated rate of deforestation (Figure 4), is arranged and published as an important environmental indicator.

The deforestation data can be combined with forest inventories and floristic survey, using geographical information systems, to provide indirect estimates of volume of wood extracted from the forest in a given area/time. An example of these estimates is shown for an Amazon municipality named Tailândia between 2001 and 2006 (Figure 5). PRODES informs that during this period of time an area of 633 Km^2 was deforested. Eight sample points of forest inventory near Tailândia with the same type of vegetation indicated a mean of 262.37 m^3/ha of wood in the area (Figure 6). By a simple operation the volume of wood extracted from this municipality can be computed as more than 16 million m^3 between 2001 and 2006. This kind of estimates could be very useful to build forest accounts. There are more them three thousand points of forest inventory in the Legal Amazon but they are outdated. The Brazilian Government intends to update it by performing a permanent forest inventory. Modern sampling techniques could be employed, using satellite images to stratify the sample, reducing de number of points to be visited in the field. This is an important support that the National Statistics Offices could give to the development of environmental statistics.

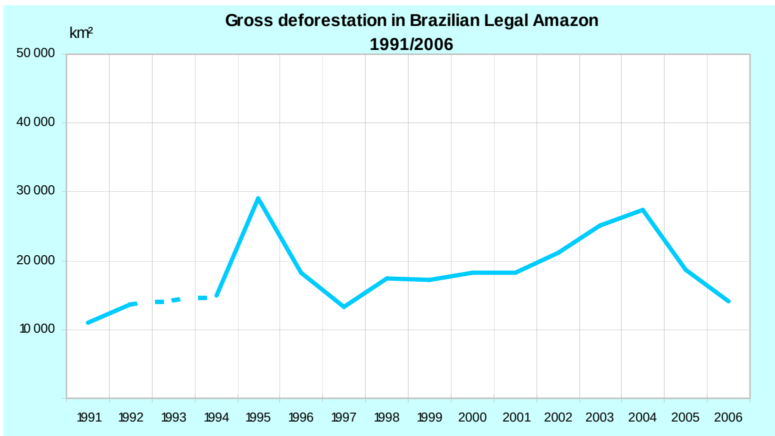

Figure 3- Gross deforestation in Brazilian Legal Amazon from 1991 to 2006

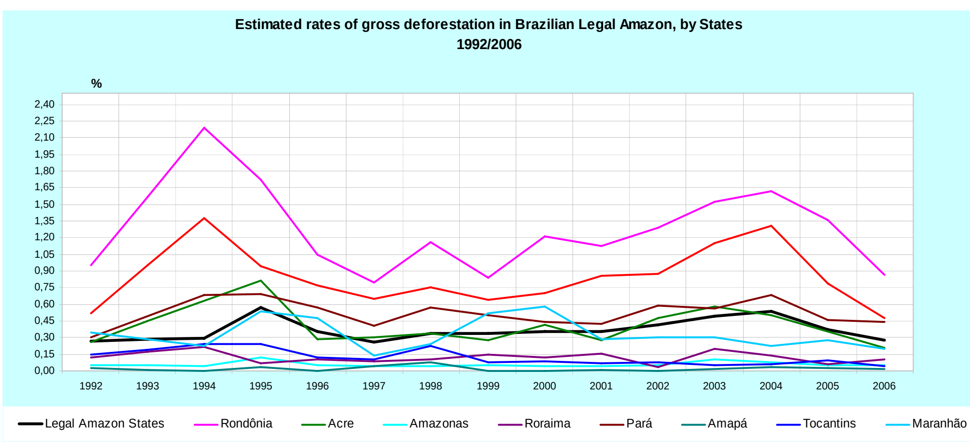

Figure 4 – Estimated rate of gross deforestation in Brazilian Legal Amazon, by States, from 1992 to 2006

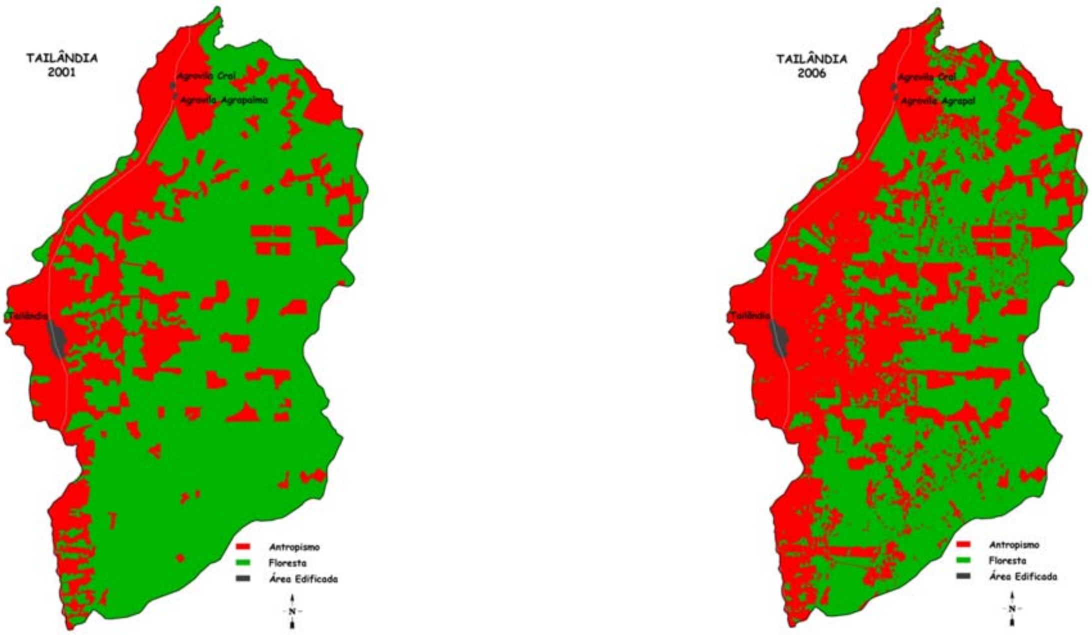

Figure 5 – Deforested area in Tailândia municipality from 2001 to 2006

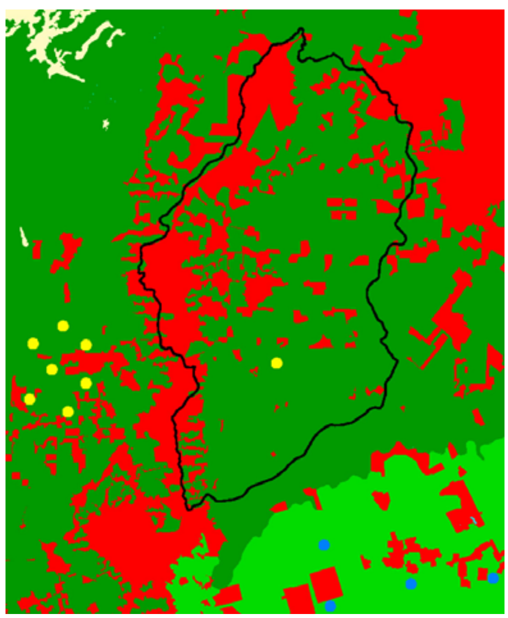

Figure 6 – Points of forest inventory sample near Tailândia municipality

BASIC STATISTICS

It is known that indicators and accounts can only be built using basic statistics, but there are some types of information that only make sense when combined with geographical occurrence. Information about rocks type is a good example of this. Ores are associated with some specific type of rock and it is necessary to know the occurrence of these types of rocks to estimate the chance of occurrence of minerals with economic interest. The data used to build the following example permits estimate that more then 50% of igneous and metamorphic rocks occurs in the Pará state. It is consistent with the economic information that Pará is one of the main mining states in Brazil for some types of ore like iron and gold (Figure 7). It is possible to identify the sites where the probability to find aquifers is higher through correlating this information to geomorphologic information.

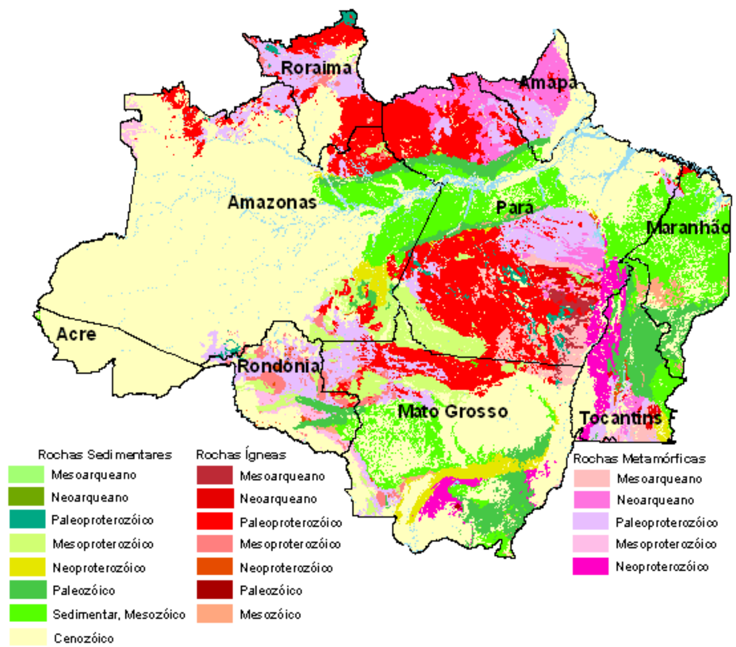

Figure 7 – Rocks according type and geological age in Brazilian Legal Amazon

ENVIRONMENTAL ACCOUNTS

Ecosystem account is one of the issues of the environmental accounts recommended in the SEEA 2003 – The Handbook of National Accounting: Integrated Environmental and Economic Accounting, but it is the issue that requires more methodological development. Even though this situation, important initiatives in the direction of constructing some standards were made by the international community. A good example is the publication of the land accounts for Europe 1990-2000 by the European Environment Agency[3]. In that paper, an approach to the ecosystem accounts by building the Land Cover Accounts in

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[3] *Land accounts for Europe 1990–2000: Towards integrated land and ecosystem accounting.* European Environment Agency. Copenhagen: 2006.

physical terms was introduced. In particular, a stock and change account for European land cover, 24 countries, 1990–2000, was presented in the Table 2.1 of that document.

Intending to test IBGE’s technical capacity to produce this kind of information and taking into account that maps of land cover and land use have been produced by IBGE for a long time, the Institute has made efforts trying to reproduce that table using the Acre state as an example. Figure 8 presents the distribution of land cover classes for 1990 and 2004, indicating an increase of pasture areas. Table 1 shows the corresponding figures. It must be emphasized that the maps used for 1990 and 2004 were not in the same scale, and as such some categories, like water bodies, could not be compared. Therefore the results were generated only for testing the methodology and should not be considered official. Indeed it is necessary more conceptual and methodological development by the technical staff to improve the study and to achieve international standards for land cover and land use classification. Despite of the mentioned limitations, the first results are very promising, showing new possibilities of analysis in this theme. Based on the test, a priority has been assigned to this topic in terms of environmental issues.

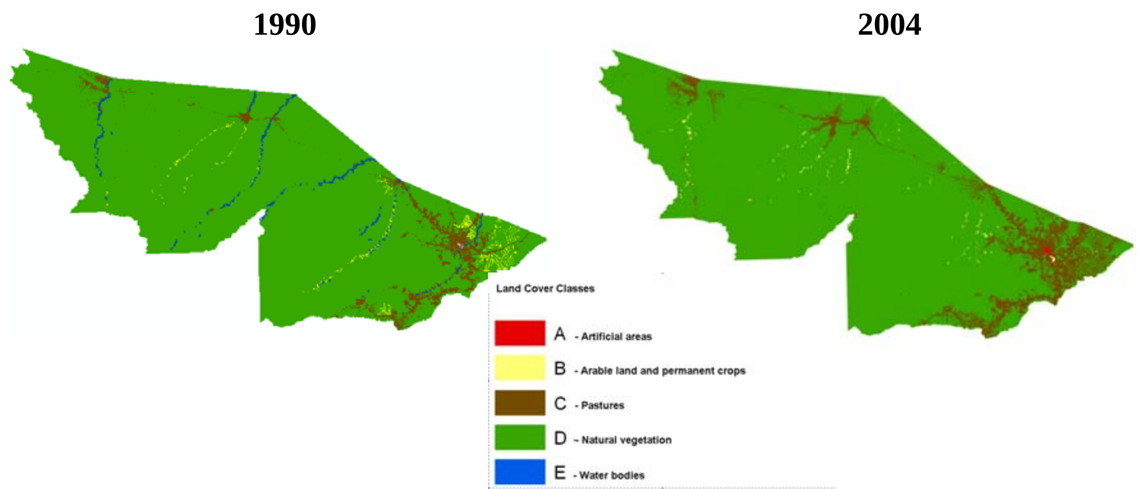

Figure 8 – Land Cover in Acre state from 1990 to 2004

Table 1 - Stock and Change Account for Acre state Land Cover from 1990 to 2004

	Artificial areas	Arable land and permanent crops	Pastures	Natural vegetation	Other misclassified
land cover in 1990 (ha)	1 589.73	123 135.92	670 471.95	15 581 901.58	26 614.73
Consumption of initial land cover (ha)	8.99	117 705.42	122 913.83	782 812.27	26 614.73
Formation of new land cover (ha)	13 417.46	50 938.84	814 402.97	171 212.44	83.52
Net formation of land cover (formation - consumption) (ha)	13 408.47	-66 766.58	691 489.15	-611 599.83	-26 531.21
Net formation as % of initial year	843.44	-54.22	103.13	-3.93	-99.66
Total turnover of land cover (consumption + formation) (ha)	13 426.46	168 644.26	937 316.80	954 024.71	26 698.25
Total turnover of land cover as % of initial year	844.58	136.96	139.80	6.12	100.31
No land cover change (ha)	1 580.74	5 430.50	547 558.12	14 799 089.31	-
No land cover change as % of initial year	99.43	4.41	81.67	94.98	-
land cover 2004 (ha)	14 998.20	56 369.34	1 361 961.10	14 970 301.75	83.52

Note: the results were generated only for testing the methodology and should not be considered official, as maps used for 1990 and 2004 were not in the same scale.

OTHER IBGE ENVIRONMENTAL PRODUCTS

Using Survey

- MUNIC – *Pesquisa de Informações Básicas Municipais* (Basic Municipal Information Survey): There is a special Environment Supplement in the Annual Municipal Survey that takes place every five years in more then five thousand municipalities, collecting the opinion of the decision makers at municipal level about several environmental issues like pollution, administrative tools in environmental governance, and others.

- PNSB - *Pesquisa Nacional de Saneamento Básico* (Basic Sanitation National Survey): It is a specific survey about basic sanitation conditions at local level, including themes like waste, sewage, water provide, and urban drawing.

Using administrative records

- IDS - *Indicadores de Desenvolvimento Sustentável* (Sustainable Development indicators): IBGE publishes every two years the Sustainable Development Indicators for Brazil, containing 22 environmental indicators out of a total of 60 indicators. To generate this publication, all types of collected information are used. For example, indicators of air and water quality are evaluated using administrative records.

Using indirect estimates

- IPPS – *Sistema de Projeção de Poluição Industrial* (Industrial Pollution Projection System): IBGE developed a pilot project using data of the state of Rio de Janeiro to estimate the potential of industrial pollution, based on information available in CEMPES - *Cadastro Central de Empresas do IBGE* (IBGE's Companies Central File) and on the technical emissions coefficients recommended by the Word Bank methodology.

There are also other studies carried out at IBGE, like Fire Impacts in Brazilian Savanna (*Cerrado*); Ecology of Endemic Fishes in the *Cerrado* (in cooperation with the National University of Brasília). In addition to that, IBGE is a collaborator of the Environment Ministry in the process of building the Ecological-economic zones division.

FINAL REMARKS

The especial configuration of IBGE, which includes the statistical and geosciences branches in the same institution, represents an advantage in terms of treating these issues in an integrated form.

IBGE is working to improve its capacity to produce, compile and organize environmental information.

IBGE is also discussing the establishment of an environmental account project with the support of United Nations Statistics Division.