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# Efficacious sustainability of GIS Development within a low income country: the Brazilian experience

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## Abstract

This article discusses the development of Geographic Information System (GIS) software and technological approaches in Brazil and their application. Issues encountered in sustaining a complex technology in a large low income country (LIC) are outlined. In the process of describing the Brazilian experience, we challenge the statements of several past authors that LICs do not possess the complex technical and human resources required by GIS technology. After a review of earlier articles that discuss the implementation of GIS in LICs, we examine the challenges, benefits and drawbacks of developing GIS software capabilities locally. We highlight a number of important applications where local technology development has contributed to better understanding and cost-effective solutions. We also consider the Brazilian case on the light of a diffusion of innovation

model. Finally, we indicate some of the potential long-term benefits of a "learning-by-doing" approach and how other countries can benefit from the Brazilian experience.

## 1 Introduction

The problems of achieving successful and sustainable use of GIS in low income countries (LIC)[1] have attracted the attention of the GIS academic community (Taylor 1991, Yapa 1991, Yeh 1991, Sahay et al. 1996, Hall 1999, Ikhuoria 1999, Ramasubramanian 1999). In general, articles on the subject are written from a "developed world" viewpoint, and emphasize case studies of (1) establishing GIS programs in developing countries with international assistance (Fürst et al. 1999, Ikhuoria 1999); (2) accomplishing projects through importation of GIS software and affiliated technologies from high income countries (HICs) (Cadwallader et al. 1999, Martinez 2000, Bocco et al. 2001); (3) initiating international training programs from universities in Europe and the US (Dunn et al. 1999) or (4) pursuing combinations of these approaches. Such studies take the perspective typically of exploring paradigms of success that might be expanded to possible later wide-ranging implementation, and, with very few exceptions, span a limited time period.

The general conclusion of the vast majority of these articles is that "technology alone is not what developing countries need" and that it is necessary to create a "culture of acceptance" for GIS in these countries, involving a combination of educating a local workforce and providing some form of foreign assistance (Hall 1999, Ramasubramanian 1999).

By contrast, considerably less attention has been paid to GIS research and development programs initiated and sustained without direct foreign financial or technical assistance. In some cases, the "developed world perspective" leads to a patronising scenario in which otherwise informed and committed scientists fail to perceive the real potential of local expertise. Taken to the extreme, this position leads to statements such as:

> *"Although there is common sense in the view that, to be useful, GIS must be introduced by indigenous scientists who understand the technological and socio-economical context in which the systems are to operate, it presupposes that such 'indigenous scientists' are already in place and are able to overcome the complex technical and human resource management problems that mire use of this technology in developing countries. If such people are in place, they are more often than not powerless to bring about real change, although in some isolated cases progress has been achieved" (Hall 1999).*

In this article, we take a different standpoint, by examining a 20-year nation-wide effort at developing local alternatives of GIS technology in Brazil. This effort has been based on the principles of *learning by doing* and stimulated by the need for large LICs have for sustainable implementation of GIS. We hope to demonstrate that the aforementioned belief that local scientists in LICs inevitably will be powerless to bring about innovation is misleading and self-defeating. In fact, we argue the opposite. We argue, based on the Brazilian experience, that investment in and dependence on qualified local expertise is the key to successful use of information technologies such as GIS in LICs. When based on thoughtful and sustained research and development programs, local teams in LICs can eschew international aid packages such as those from the World Bank while providing more appropriate information technology solutions for their nations. Rather than viewed as mere dependents, such research teams are able to relate to "developed world" scientists as mutually respected partners and valued contributors to intellectual discourse and scientific advancement.

*Appropriate technology* is ultimately that which is suitable and accessible (Schumacher 1973). We offer evidence that GIS software developed within LICs has the potential for being more responsive to the specific needs of many users in lower income nations and can provide more widespread access to useful GIS technology than typically is allowed by dependence on imported software.

We also examine the crucial role that local research and development may play in fostering new technology generally in developing nations. We suggest that concerted software development efforts within LICs can provide the means for creating a core of technically competent software engineers and system managers who are then able to lead training, implementation, and further information system developments over time, thereby reducing dependence on foreign expertise and aid.

## 2 Research, development and applications of GIS in Brazil

In order to explore the benefits and limitations of such local research and development efforts through experiences with a major GIS development effort in a LIC, we examine the approach taken in Brazil by a team of institutions led by INPE (National Institute for Space Research) to develop GIS in an "sustainable technology" context.

### *2.1 The Institutional Setting*

INPE (National Institute for Space Research) is the primary Brazilian institution for research and development in space-related fields. INPE is responsible for different activities involving spatial data, including: (a) operation of a remote sensing ground station receiving LANDSAT data since 1974 and SPOT data since 1986, including management of one of the largest archives of remotely sensed data in the world, (b) creation of a Remote Sensing Division in 1972, which has been conducting research and application projects and that conducts a graduate program in Remote Sensing and GIS that has granted more than 150 Masters degrees since 1974 (a Ph.D. program was started in 1998); (c) operation of a numerical weather prediction and climate centre (CPTEC) which issues forecasts and climate analysis, with many products available online, and (d) development of remote sensing satellites, including the CBERS series of satellites (a LANDSAT-class satellite) built in co-operation with China. The CBERS-1 satellite has been launched in October 1999, carrying a CCD detector with 5 multispectral bands and 1 panchromatic band with 20 meter resolution for the visible and near infrared regions, and a MSS detector with 80 meter resolution with 4 multispectral bands for the mid-infrared portion of the spectra.

During the 80s, aiming at the protection of the local information technology industry, the Brazilian Government adopted a “market reserve” policy. For eight years, through Law 7232/84, there was a heavy economic incentive provided by the government to produce local information technology (IT) hardware goods. Further, strong restrictions were imposed on IT imports as well as on the local products of companies that did not fit the then-existing concept of a ‘domestic-capital Brazilian company’ (Silva 1997). The market reserve for hardware was later removed in 1992 and the distinction between ‘domestic-capital Brazilian company’ and ‘foreign-capital Brazilian company’ was eliminated in 1995. The current legislation (Law 10.176/2001) provides limited protection to local IT industries in the form of tax incentives, regardless of their capital origin.

Throughout the period of hardware regulation there was no specific protection for local software production. Legislation passed in 1987 (Law 7646/87) essentially allows for the unrestricted import of software goods.

The ‘market reserve’ law of 1984 provided a powerful incentive for local development of GIS and Remote Sensing Image Processing technology, insofar as a typical price for a single-seat system at this time was approximately US$ 100,000, inclusive of hardware, software and training costs. The government requested INPE to devise a strategy for local development of such technology. Therefore, in 1984, INPE established its Image Processing Division (DPI) with the following aims: (a) local development and dissemination of image processing and GIS systems in Brazil; (b) establishment of a research program in Image Processing and GIS, and (c) pursuit of co-operative programs with universities, government organisations and private companies. INPE also later established a start-up company, called *Engespaço*, that would provide for the manufacturing of such products and customer assistance .

In 1984, a key decision was made to assemble a group of computer specialists to work alongside the existing group of remote sensing application experts. Therefore, one of the important differences between INPE’s staff and other groups involved in GIS is that the group is largely composed of an interdisciplinary combination of Computer specialists and Remote Sensing researchers. This unique mix of competence has had a major positive impact in assuring that resulting technologies would meet meaningful user requirements.

The DPI staff is currently composed of 12 PhDs and 22 Master's (mostly in Computer Science and GIS) as well as 10 senior engineers and 12 graduate students. Staff members have published more than 100 scientific papers in refereed journals and in national and international refereed conference proceedings. Funding for its activities comes mainly from the Brazilian government through its research agencies. Staff members have never sought or received grants from international development or aid agencies such as the UN or the World Bank.

### *2.2 Project history*

In 1984, all GIS and image processing (IP) solutions were mainframe-based. Therefore, INPE decided to concentrate on the development of low-end solutions. In 1986, the group brought out Brazil's first GIS+IP system (SITIM) which worked on MS-DOS PC-286, with a home-grown add-on graphics card that had a resolution of 1024x1024x24 bits. SITIM had been designed to a very tight level of integration between IP and GIS and SITIM was used extensively by 150 universities and research labs, up to 1996.

In 1992, given recent advances in hardware and software and the changes in information technology policy in Brazil, DPI/INPE started the development of SPRING, whose first Internet version was made available in late 1996. SPRING provides a comprehensive set of functions for processing of spatial information, including tools for Satellite Image

Processing, Digital Terrain Modelling, Spatial Analysis, Geostatistics, Spatial Statistics, Spatial Databases and Map Management (see Appendix 1 for a list of primary functions). SPRING has required over 170 man/years of development and includes extensive documentation, tutorials and examples. Tools for the publication of geographic data on the Internet are also provided by means of an add-on module (SPRINGWeb), a Java applet, that allows remote access to spatial data sets.

The SPRING software includes a number of innovations, including many which predated other GIS, either commercial or non-commercial:

- An object-oriented data model for spatial data (Câmara et al. 1994, Câmara et al. 1996) and an object-oriented data query and manipulation language (Câmara et al. 1994)

- A region-growing segmentation and a region-based classification algorithm (Shimabukuro et al. 1998), an algorithm for combined interpolation-restoration of Landsat images through FIR filter design (Fonseca et al. 1993) and support for mixture models for image processing, and Markov-based techniques for image post-classification (Frery et al. 1993).

- Integration of geostatistical and spatial statistics tools in a GIS environment (Felgueiras et al. 1999).

The software has compatible versions for Windows 95/98/Me/NT and Linux and is available on the Web at no cost (http://www.dpi.inpe.br/spring). Mirror sites for SPRING have been set in Spain (University of Bergara) and Bolivia (Geological Survey). The evolution of SPRING downloads since 1997 is shown in Table 1. In 1997, there were 500 access by different individuals and organisations. In 1998, after a Windows version was available, the count jumped to 2000. At the end of year 2000, it had gone to 8000, and around 46000 users have obtained SPRING by the end of 2004. This steep upward trend is consistent with the Rogers model, insofar as is pre-conditions are observed, as indicated below (Rogers 1995).

TABLE 1 – EVOLUTION OF SPRING DOWNLOADS (NEW USERS)

| Year | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| SPRING downloads (acc) | 500 | 2.000 | 3.500 | 4.500 | 9.000 | 10.500 | 8.500 | 8.000 |

In addition to its local development of software and documentation, INPE has coordinated an effort to develop a comprehensive reference work on GIS. The volume follows a similar organisation to the now "standard" book on GIS by Longley et al (1997). Written in Portuguese and available on-line, it is arguably the most complete resource of its kind on the Internet today. The response from GIS users in Brazil has been extremely positive, not only from GIS students and government officials but also from small private start-up companies specialising in GIS and small surveying firms that have wanted to enhance their capabilities.

Out of a large number of applications developed using SPRING, a few significant examples are listed in the Appendix. In addition, a number of public and private Brazilian environmental organisations use SPRING and the system is being used as teaching aid in many universities throughout Brazil and Latin America.

### *2.3 Establishing a stakeholder strategy*

From very early on the SITIM and SPRING project development, it was recognised that production of state-of-the-art software technology in LICs requires a very different form of interaction between the academic and industrial sectors. In more advanced economies, software development is usually the product of fierce competition among industries. In countries such as Brazil, few companies have the economic and human resources needed for long-term software development. Co-operation rather than competition often is the key for successful software projects in developing countries.

Therefore, it was necessary to bring together a network of institutions and leading scientists, who would be interested in becoming “stakeholders” for the local Brazilian development efforts. These institutions now include: (a) EMBRAPA (National Agricultural Research Agency), which has 50 research centres and more than 1,500 PhDs.; (b) PETROBRAS, one of the world’s largest petroleum companies, through its research and development centre; (c) MMA (Ministry of the Environment), through its Sustainable Development directorate; (d) CNPq (the National Research Council); (e) Leading scientific societies such as SBC (the Brazilian Computing Society) and SBPC (Brazilian Society of Scientific Advancement). Ties were also forged with politicians which were part of the Science and Technology commissions of both the Congress and Senate of Brazil.

Additionally, there has been an effort to support private start-up companies in GIS services. At least a dozen such companies were started with software and support provided by INPE, at two of them are among the leading providers of GIS-related services in Brazil, with a total of more than 200 employees.

### *2.4 International partnerships and their impact on the project*

It has been well documented in the literature that industrialised countries refrain from actively supporting the development of advanced technologies in developing countries, and seek to influence decision-makers to remain consumers of Western products (Landes 1999). When sophisticated technological development is at stake, it is very difficult to establish fruitful North-South partnerships between governments, aid agencies and private companies.

The more fruitful North-South partnerships are those on a person-to-person basis, as in the case of research collaborations between university professors. In this respect, the SITIM and SPRING have benefited from scientific ties with leading centres of GIS and Remote Sensing research in the USA and Europe, including: (a) The Department of Spatial Information Science and Engineering at the University of Maine (prof. Max Egenhofer); (b) The Department of Geography at the University of California at Santa Barbara (prof. Michael Goodchild); (c) The Department of Electrical and Computer Engineering at the University of California at Santa Barbara (prof. B.S.Manjunath); (d) the Centre for Earth Observation Science at the University of Sheffield (prof. Shaun Quegan); (e) the Institut für Hochfrequenztechnik und Radarsysteme at the DLR, German Aerospace Center (prof. Alberto Moreira).

## 3 SPRING and the diffusion of GIS innovation in Brazil

The Diffusion of Innovations model as originally articulated by Everett Rogers (Rogers 1962) and explored in thousands of subsequent research studies indicates that the characteristics of an innovation, as perceived by the members of a social system, help determine its rate of adoption. Five *attributes* that aid explanation of the rate of adoption of an innovation include: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. In addition to these attributes, additional *variables* that help explain an innovations rate of adoption include (1) the type of innovation-decision, (2) the nature of communication channels diffusing the innovation at various stages in the innovation-decision process, (3) the nature of the social system in which the innovation is diffusing, and (4) the extent of change agents' promotion efforts in diffusing the innovation. (Rogers 1995).

Usually the attributes of an innovation are taken as unchangeable and therefore those attempting to hasten the adoption of a beneficial innovation typically focus on altering the variables affecting adoption. By example, in regard to the type of innovation decision, the more people involved in an adoption decision the slower will be the adoption process. Thus, to hasten a decision, organisational consultants might attempt to arrange relegation of authority to make a specific adoption decision to one or a small group of individuals in an organisation. By using a variety of similar techniques to alter the innovation-decision variables, the process of adoption may be hastened.

While those attempting to speed up the rate of adoption of an innovation often focus on the latter four variables, we note that software designers and those controlling the intellectual property rights in an information innovation often hold the power to alter the actual attributes of such an innovation. Adaptation of GIS software, support and use rights to meet the needs of low income countries may help explain why SPRING has spread at a more rapid rate of adoption and has reached a larger portion of the population of potential users in Brazil than most commercial alternatives.

Actual rates of adoption of SPRING technology can be estimated, based on the evolution of the number of users that have downloaded it, since the software was first put on the Internet, on December 1996, shown in table .

***Relative Advantage***

> "Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes" (Rogers 1995, p 212)

For some adopters, the idea that SPRING superseded was the replacement of a mainframe GIS or commercial desktop GIS with SPRING in order to accomplish the same or similar management and analysis tasks at far less cost. It had the relative advantage of requiring no capital investment for software, no support or maintenance fees over time, and free technical support in the native language of the nation. SPRING also had the relative advantage of having a superior ability to perform such tasks as the integration of remote sensing data in a GIS. For most potential users however, the choice was between continuing to use manual methods to accomplish spatial management and spatial analysis tasks or using SPRING to accomplish such tasks. Most commercial alternatives and even the IDRISI alternative were simply unavailable to potential users from a capital expenditure perspective. In addition, switching to SPRING may have conferred the relative advantage of increased prestige to some adopters resulting from the use of an affordable computerised desktop system over the prior manual methods or resulting from increased analysis capabilities.

### *Compatibility*

> "Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters." (Rogers 1995, p 224)

An innovation can only be assessed based on what is already familiar. The diffusion of SPRING benefited from the familiarity of some users with GIS software and capabilities imported from HICs. GIS was already recognised as a valuable tool for meeting many of the pressing needs of the LICs such as monitoring changes in land use and deriving suitability models for agricultural projects. When felt needs are met by an innovation a faster rate of adoption is likely to occur. Not only does SPRING fill a gap in being able to address a range of applications but it meets a need in being more compatible with the language and culture of Brazil. The availability of SPRING has been coupled with an extensive done by INPE on human resources qualification. In the last five years, more than 2,000 students attended short courses on SPRING and various aspects of GIS.

***Complexity***

> "Complexity is the degree to which an innovation is perceived as relatively difficult to understand and to use." (Rogers 1995, p 242)

Radios and phones are technologies that are very easy to use whereas practical use of a GIS is far more difficult. However, the complexity in use of a GIS can be and has been continually reduced through the efforts of software and hardware developers over time. In order to reduce the complexity of GIS adoption to the average use in a LIC, the developers of SPRING have worked in two fronts: (a) the adoption of an object-oriented user interface, which unifies handling of the different types of spatial data; (b) emphasis on user training and production of GIS reference material. This lesser degree in complexity in accomplishment of at least these tasks can be expected to correlate positively with the rate of adoption.

***Trialability***

> "Trialability is the degree to which an innovation may be experimented with on a limited basis." (Rogers 1995, p 243)

Because the software is freely available, users may try out the full capabilities of the system without overcoming an economic hurdle for its acquisition. Because the software commands, help documentation, support literature and phone help are fully available in Portuguese (and Spanish), the ability of non-English speakers to play with and experiment with SPRING relative to the specific needs of a particular organisation is greatly enhanced.

This increased trialability for many potential users within the LICs population base is positively correlated to the rate of adoption.

***Observability***

> "Observability is the degree to which the results of an innovation are visible to others." (Rogers 1995, p 244)

When the advantages of an innovation become highly observable to others in the social system who might similarly adopt, they are far more likely to adopt. Factors affecting observability often include the extent of access to those in the social group that have adopted, the success of those adopters, and the extent of belief that adoption helps explain the success of the organisation or individual as compared to other variables. The existence of SPRING on the desktops of peers attempting to accomplish similar spatial information processing tasks, their success in accomplishing those tasks, and its availability in the native language of the nation made SPRING far more observable to other potential users in Brazil. A second positive factor has been the use of SPRING as a basic tool for students in undergraduate and graduate courses in GIS in INPE and in many universities in Brazil. These observability factors probably had a positive correlation with the rate of its diffusion.

The next major phase of planned improvements to the existing GIS capabilities (see Section 4.1) will incorporate adjustments by software developers and system stewards to the above listed attributes in order to increase the likelihood that the new capabilities will diffuse rapidly among current and expanded populations of LIC users.

## 4 Long-term benefits of local development

An important consequence of pursuing a "learning by doing" approach combined with substantial investment in local human resources is the capacity for developing a critical perspective of GIS.

Comparing different commercial solutions can be very difficult. GIS managers in LICs that lack in-depth knowledge of the characteristics and capabilities of GIS options relative to their specific application needs are disadvantaged in their GIS adoption decision making. In the Brazilian case, an important benefit resulting from the development of SPRING has been a very complete understanding of the “core” aspects of GIS technology and a capacity by involved staff to dissect the so-called “black-box” commercial solutions in order to understand their strengths and weaknesses.

A second benefit of the “learning-by-doing” approach is the possibility of establishing a technological strategy that allows for production of continuous innovation. In the case of GIS, the industry is bound to witness substantial change in the upcoming years, induced by technological advances in spatial databases. Current and expected advances in database technology will enable, in the next few years, the complete integration of spatial data types in data base management systems (Shekhar et al. 1999). This integration is bound to change completely the development of GIS technology, enabling a transition from the monolithic systems of today (that contain hundreds of functions) to a generation of *spatial information appliances*, small systems tailored to specific user needs. The transition from file-based GIS systems to spatial databases will also enable different applications to use the same data, as also is being proposed by the OpenGIS consortium (OGC 1996).

Motivated by the database paradigm shift and backed by its previous experience in SITIM and SPRING, the INPE group is currently developing **TerraLib**, an open-source GIS component library. TerraLib enables quick development of custom-built applications using spatial databases. Currently, such capabilities are only available by means of proprietary solutions such as COM components available in products such as MapObjects, GeoMedia and ARC/INFO-8. These components are based on transitional technologies that either duplicate in memory the data available in the DBMS or use additional access mechanisms such as ArcSDE. **TerraLib** aims to improve on such capabilities by providing direct access to a spatial database without unnecessary middleware.

As a research tool, TerraLib aims to enable the development of GIS prototypes that include new concepts such as spatio-temporal data models (Hornsby et al. 2000), geographical ontologies (Fonseca et al. 1999) and advanced spatial analysis techniques (Heuvelink 1998). TerraLib's partners include TECGRAF/PUC-RIO (Computer Graphics Group at the Catholic University in Rio de Janeiro).

The authors consider that the geographical information community would benefit from the availability of a general, open source GIS library. This resource would make a positive impact by allowing researchers and solution developers access to a wider range of tools than what is currently offered by the commercial companies. In a similar approach to the Linux and subsequent open source software efforts, we recognise that such development does not happen by spontaneous growth. There must be created a core set of technologies from which further developments may freely extend.

Our proposal for the development of the **TerraLib** spatial library aims precisely at offering the GIS community a basis for further development. The current intent, although open to debate and further consideration, is that the TerraLib spatial library will be licensed using the GNU Library License (or Lesser General Public License - LGPL), thereby allowing spatial information appliances developed by both the commercial and open source communities to be built from the library. While our intent is to not force commercial companies utilising the library to make their appliances open source, we ourselves intend to develop several core open source spatial information appliances using the GNU General Public License (GPL) and will encourage others to develop similar open source spatial information appliances which if built upon will need to also utilise the GPL license. Through this approach, we believe those from LICs will be better able to actively participate in developing application software meeting the needs of their own nations and the needs of similarly situated individuals and organisations throughout the world.

## 5 In conclusion: the place for low income country technology in a global market

Is there a place in the global information environment for technology originating from LICs? This paper has argued in the affirmative, especially when such technology is primarily directed towards serving users' needs in those same countries.

The challenges involved in developing technology in LICs include not only establishing a team of qualified personnel, but most importantly, forging a long-term investment perspective from local governments. Arguably the most difficult impediments are of a cultural nature. Many local decision-makers have such a colonised view of world affairs that they mistrust their own institutions and people, thus creating a self-sustained circle of domination. This situation is made worse by the approach taken by many international agencies, that usually finance technology purchases but will not finance knowledge acquisition.

Therefore, challenges faced by GIS implementers in LICs cannot be addressed solely by improving the traditional mechanisms of foreign aid. It is necessary to build a situation where people from LICs actively co-operate (including mindful and committed partners from high-income countries) to share resources and knowledge and to build information technology solutions that are meaningful to them.

In conclusion, we have attempted in this article to discuss the development of GIS in LICs from the perspective of a local institution that has largely depended on its own strengths. Our main conclusions are that the sustainable build-up of skilled local experts is a fundamental and indispensable step for effective use of GIS in LICs and that the SPRING project is an example of what may be achieved given time and effort. We hope to have established that the self-defeating perspective as stated in many previous journal articles, while based on actual experiences, represents a gross underestimation of the capabilities of people and institutions in lower income nations.

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# APPENDIX

## TABLE 2 – SPRING FUNCTIONS

| Component | Functions |
| --- | --- |
| **Data Base and Query operations** | Attribute and Spatial Queries;<br>Thematic Map Generation<br>Interfaces to dBASE, ACCESS and ORACLE relational databases. |
| **Image Processing** | Registration and Geometric Correction;<br>Image Mosaicking, Image Enhancement; Spatial Filtering, IHS and Principal Components Transformations.<br>Maximum-likelihood pixel-based classifier; Image Segmentation and Region Classifiers (Supervised and Unsupervised); LANDSAT and SPOT Image Restoration; Mixture Models; Markov-based Post-Classification; Radar Image Processing. |
| **Map Algebra** | LEGAL Map Algebra Language, implements Reclassification, Weighting, Slicing, Boolean Operations, Fuzzy and Zonal Operators, and conversion between field and object representations.<br>Decision Support by the AHP method.<br>Buffer Analysis. |
| **Spatial Analysis** | Point Pattern Analysis (kernel estimation, K-function).<br>Geostatistics: Variogram estimation, Linear and Non-linear Kriging; Analysis of Area data: global and Local autocorrelation indicators. |
| **Network Modeling** | Digitizing of lines and nodes of a network; Association with objects and definition of impedances and demands;<br>Shortest Path Calculation; Location Analysis: P-Median. |
| **Digital Terrain Modeling** | Sample Points, Contour Lines and breaklines Digitizing; Generation of Regular Grid and TIN (with breaklines); Contour Plotting; Slope and Aspect Maps; 3D Visualization. |
| **Map Production** | Interactive environment (WYSIWYG) for maps with symbol, legend and text positioning control. Support for Windows and PS printing. |
| **Data Management** | Digitizing, Editing and Topology Creation; Raster to Vector and Vector to Raster Conversion; Support to 14 Cartographical Projections; Vector and Image Mosaicking; Vector Cleaning; |
| **Data Import and Export** | Vector: ARC/INFO, SHP, MIF, ASCII, DXF.<br>Grid: ARC/INFO, ASCII, SGI;<br>Image: RAW, TIFF, GeoTIFF<br>Table: dBASE, ASCII, ACCESS and ORACLE; |

TABLE 3

SELECTED LARGE-SCALE GIS APPLICATIONS IN BRAZIL USING SPRING

| **Application** | **Organizations Involved** | Data Types |
|---|---|---|
| Amazon Forest Deforestation Assessment (1.500.000 $km^2$) | INPE, Environmental Protection Agency (IBAMA) | LANDSAT images, Vegetation maps, Topographic maps |
| Ecological-Economical Zoning of Brazil | Ministry for the Environment, Census Bureau (IBGE), Geological Survey | Vegetation, Soils, Geological, Geomorphology maps, LANDSAT images |
| Monitoring of Climate Risks for Agriculture (3.000.000 $km^2$) | EMBRAPA (Agricultural Research Agency) | Agricultural, Soils, Climate data |
| Social Exclusion Map of São Paulo | Catholic University of São Paulo | Census and socio-economical data |
| Climate Monitoring in the Brazilian Northeast | Centre for Weather Prediction and Climate Studies (CPTEC), Ministry for Internal Affairs | Soil surveys, climate data, LANDSAT imagery, census data |
| Monitoring of Vegetation Fires in Brazil | Centre for Weather Prediction and Climate Studies (CPTEC), Environmental Protection Agency (IBAMA) | AVHRR images, climate data, LANDSAT imagery, census data |

[1] The term "low income country" (LIC) is used as a preferred term in this article when it accurately describes a general group of nations. The concepts of "first", "second" and "third world" nations arose in U.S. and European society as a designation for major groups of countries during the Cold War. Major economies siding with U.S. and European concepts of capitalism were referred to as "first world" nations whereas major economies based on communist principles such as the USSR and China were referred to as "second world" nations. The remaining nations and particularly those nations with low per capita income came to be labeled as "third world" nations. This classification scheme is looked upon with disfavor in most of the world since it implies a hierarchical class system. Most nations also object to being labeled as an "undeveloped nation" because in fact the culture and governance structure for a nation may be very well developed and sophisticated even though such a nation may have very limited economic resources. To many, the term "developing country" implies similar negative connotations. Further, terms such as "emerging nation" and "developing country" are misnomers when applied to a nation in which the economy in fact may be stagnant or backsliding rather than emerging. With sensitivity to the possible negative connotations of the alternative terms, we strive in this article to use the terms "lower income country" (LIC) and "higher income country" when appropriate but resort to other terms when they more accurately describe a group of nations.

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