

Remote Sensing Research at the State University of Campinas, Brazil

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1. Introduction

The State University of Campinas (UNICAMP) is one of Brazil's foremost universities, being responsible for 15% of the country's scientific publications. Every year, over 50,000 students from all over the country apply to enter one of the university's 60 undergraduate courses, and only 10% meet the strict entrance examinations. Created over 35 years ago to be a research-oriented university, half of its 30,000 students are enrolled in graduate programs, and the University awards every year 1000 Masters and 700 PhD degrees. Still another 14,000 people are enrolled in continuing education courses. This student body is taught by 1800 faculty, 97% of which have PhD degrees. This profile of student and faculty qualification, allied to good research facilities, provide very good opportunities for innovative research, involving both graduate and undergraduate students.

Remote sensing (RS) research, by nature multidisciplinary, has found in UNICAMP a good environment to flourish. Several laboratories conduct work on different aspects of the use of this technology, involving faculty with distinct profiles. Rather than one single center dedicated to RS aspects, several laboratories develop initiatives in this area, with distinct application domains in mind. This paper gives a brief overview of the work conducted along two distinct domains – agriculture and geology – with projects resulting from cooperation of experts in computer science and in the study and application of RS to these domains. It must be stressed that other groups in the university also conduct work involving remote sensing technology – e.g., for biodiversity analysis – but this paper presents a good sample of relevant ongoing projects. The authors work in four distinct laboratories, but collaborate in various research and training activities. As will be seen, a few of the projects described in the sections that follow involve people from all laboratories concerned.

Section 2 presents some aspects of the research conducted at the Institute of Geosciences, in its Laboratory for Geo-referenced Information (LAPIG). Section 3 describes work conducted in the GEO laboratory at the Agriculture Engineering Faculty. Section 4 discusses research developed at CEPAGRI - Center of Meteorological and Climatic Research Applied to the Agriculture. Section 5 outlines initiatives in the Institute of Computing within the Laboratory of Information Systems. Finally, Section 6 briefly mentions the graduate and undergraduate degrees offered by the University that include remote sensing studies.

2. The Laboratory for Geo-Referenced Information Processing at the Institute of Geosciences

2.1. Introduction

The Laboratory for Geo-Referenced Information Processing (LAPIG) was established in 1990 in the Institute of Geosciences, with Brazilian and international funding (Eximbank). Being the primary academic facility of its kind in Brazil, LAPIG has comprised one of the most important research groups in remote sensing (RS) data processing and GIS applied to Geology. Its Research Group on Geo-technologies Applied to Natural Resources is presently composed of several faculty members, including 6 Lecturers, 1 post-doctoral fellow, 8 Ph.D. students, 12 MSc. students, 20 undergraduate students and 2 professionals of the computing staff.

Among several key features, LAPIG involves a comprehensive image processing suite of hardware and software. Installed in 1998, the Spectroscopy Laboratory (Spec-Lab) works as a supporting lab within LAPIG's infrastructure, hosting world-class spectroscopy instruments and accessories, including a FielSpec Full Resolution (350-2500nm) spectrometer – the first acquired within research institutions in South America.

As a teaching facility, LAPIG is also a reference as a remote sensing graduate program, with nearly 40 master's dissertations and doctorate theses concluded since the lab was established. It currently receives graduate students from Brazil and other Latin-American countries, besides supporting undergraduate teaching for Geology and Geography students.

The objectives of LAPIG are to develop algorithms and methodologies for data processing and information extraction from remote sensing sensors in the optical and microwave ranges, airborne geophysical and seismic data, as well as to develop technologies for geological, spectral, geophysical and geochemical data processing and integration using geo-referenced information systems (GIS) and expert systems. In terms of education, the objectives include to train students in the use and development of the Geo-technologies.

Major research themes at LAPIG are in multi-hyperspectral, SAR and airborne geophysics data processing and spatial data modeling, applied for mineral and geologic mapping, oil seep detection, environmental monitoring, among others. Some of the research results are presented in the following sections.

2.2 Multi and Hyperspectral Image Processing

Spectrally-oriented processing has been one of the main research focus at LAPIG, starting with 7-band Landsat/TM and ETM+ and moving progressively into higher resolution imaging sensors, such as Terra/ASTER (14 bands), GEOSCAN (24 bands, airborne), SIPAM R-99-B/MSS (11 or 33 bands, airborne), SIPAM R-98/HSS (50 bands, airborne), AVIRIS (224 bands, airborne) and EO-1/Hyperion (210 bands). The spectral dimension of the information provided by these sensors offer an insight into the chemical composition of surface materials. The main application of spectral processing at LAPIG is mineral mapping. In order to derive mineral composition and abundance from the images acquired by these sensors, specific information extraction tools are developed and applied at LAPIG.

An example of principal component analysis as a spectral mapping algorithm is presented in Figure 1. By selecting proper ASTER bands, based on their position along the electromagnetic spectrum, and applying PCA, it is possible to isolate and map spectral features due to certain minerals (called alteration minerals) which are indicators of possible metallic deposits, such as gold. This is a multispectral approach to mineral mapping, which may be used as a qualitative tool for covering large extensions of poorly geologically known terrains in the search for mineral deposits, as in the case of the Argentinean Patagonia shown in Figure 1.

A more quantitative approach to the same problem is given by the use of hyperspectral processing tools, applied to multispectral ASTER data. By using reference spectra (measured with a reflectance spectro-radiometer) from ground targets, representing either pure minerals or mixtures of them, and using them as input endmembers in a hyperspectral processing algorithm, such as mixture tuned matched filtering (MTMF), it is possible to achieve a detailed spectral mapping of alteration minerals. **Figure 2** shows the results of this approach, for the same area in Patagonia shown in Figure 1.

2.3 SAR Texture Processing and Integration with Airborne Geophysics

Airborne geophysical (magnetic and gamma-ray spectrometry) and SAR data processing and their integrated interpretation are also part of the research carried out at LAPIG. Considering that Brazil is a tropical country, geologic mapping in places such as the Amazon is severely constrained by the lack of bedrock exposure, the presence of dense vegetation cover and thick soil/weathering profiles. The use of specially tailored algorithms (e.g., step-wise textural classifiers, feature-oriented principal component analysis, spectrally-tuned IHS transform) for handling such complex data has allowed, for example, a detailed structural and geologic mapping in places such as the Tapajós Mineral Province (central Amazon) – see Figure 3. Results derived through these geotechnologies proved important in delineating gamma-ray and textural domains where particular gold mineralization occur in the Amazon, a notion that has been extended for several applications in the region.

2.4 Spatial Data Modelling

LAPIG also conducts innovative work concerning spatial data modeling software focused on geologic applications. Among recent efforts, the lab's team has been involved in recent upgrades of the Arc Spatial Data Modeler software (ArcSDM-3), in collaboration with the United States Geologic Survey (Dr Gary Raynes), the Canadian Geologic Survey (Graeme Bonham-Carter) and several mining companies and research institutions worldwide. ArcSDM is a package designed to model spatial data using weights of evidence, logistic regression, fuzzy logic, neural network

analysis, among other features. These advanced tools provide the necessary foundation for the construction of knowledge and data-driven models that can assist in geologic exploration of precious and base metals.

As a way of illustration, **Figure 4** shows an example of an application of ArcSDM in the Iron Quadrangle region, SE Brazil. Based on known gold occurrences and mines, it was possible to develop predictive models and favorable prospecting sites for gold mineralizations, including places where no occurrences were recognized by exploration geologists previously.

3. Remote sensing and agriculture – crop monitoring studies

The Geoprocessing Laboratory (LABGEO) is located at the Faculty of Agricultural Engineering. At present, 3 PhD and 3 MSc students are developing their research in this lab. Seven other faculty members contribute to this work; some of these faculty work in Agricultural Engineering, whereas others work at the Institute of Computing (see section 5) and the Faculty of Civil Engineering. The lab also offers opportunities for insertion of good undergraduate students in advanced research – presently, there are 20 students cooperating in this work.

LABGEO meets the GIS/Remote Sensing demands of the undergraduate and graduate courses in agricultural engineering and is home of the GEO (Geoprocessing Group), an official research group registered at the National Council for Scientific and Technological Development (CNPq – Ministry of Science and Technology), Brazil. Its team of lecturers, researchers and graduate students of GIS/Remote Sensing carries out research/consultancy/training in GIS/Remote Sensing applied to Environmental Planning, Precision Agriculture and Crop Monitoring. Currently the main research topics are:

- Watershed management and impact assessment (soil erosion, soil degradation mapping and modelling)
- Remote sensing applied to land use mapping, crop variability mapping, crop monitoring and crop yield estimates at local, regional and national levels
- Scaling up information on crop condition from higher to lower resolution satellites. Figure 5 shows an example of this kind of activity, and the different transformations needed among satellite data.

The Geoprocessing Lab is a key partner of projects like WebMaps (see Section 5), developed in cooperation with other university labs, and the Geosafra Project, a 14 institution project to develop crop monitoring methodologies for the Brazilian Ministry of Agriculture. The laboratory also has close ties with the European Commission – Joint Research Center, in crop monitoring for food security in the Mercosur countries.

4. Remote sensing and agriculture – the Center of Meteorological and Climatic Research applied to Agriculture

CEPAGRI (Center of Meteorological and Climatic Research Applied to the Agriculture) was created in November 1983. Its main research areas are agrometeorology, agroclimatology, geotechnologies (with emphasis in remote sensing applied to agriculture) and ecophysiology. In a recent institutional evaluation within UNICAMP, the Center was rated at the top “Excellence Level”, due to its many interdisciplinary activities and research productivity.

Besides its many research activities, CEPAGRI also has an operational service of supplying meteorological and climatic data and information to the Civil Defense, press, tourism agencies, transport companies and population in general. CEPAGRI’s webpage (see references) is one of the first of its type in Brazil, providing information, data and images related with meteorology and climatology since May 1995.

Together with CNPTIA (the Center of Informatics for Agriculture of EMBRAPA - the Brazilian Ministry of Agriculture Research Center), CEPAGRI has an extension service in the internet since 2003 called Agritempo (www.agritempo.gov.br). This service supplies daily updated meteorological and climatic data and images applied to agriculture, for the whole country.

Besides research and extension activities, the researchers of CEPAGRI take part in teaching graduate and undergraduate courses, as well as in supervising MSc and PhD students. CEPAGRI has scientific cooperation programs with several Brazilian institutions such as the Agriculture Department (MAPA), Agronomical Institute of Campinas (IAC), Agronomical Institute of Paraná (IAPAR), EMBRAPA, Astronomical and Geophysical Institute (IAG/USP), National Institute for Space Research (INPE) and IPMET/UNESP. At the international level, there are scientific cooperation programs with institutions such as the Institut National de la Recherche Agronomique (INRA)/France, Instituto Nacional de Tecnología Agropecuária (INTA)/Argentina and Universidad de València/Spain.

The main research programs of CEPAGRI are the following:

Agricultural Zoning - This is a National Program based on integration of crop growth models, climate and soil data bases, decision analysis techniques and geoprocessing tools used to define planting calendars for the main agricultural crops (such as rice, beans, corn, soybean, wheat, sorghum, cotton, coffee and fruits) that are updated every year since 1995. This program has been used as a basis for establishing federal farm credit policies. Official lending agencies for rural programs have to use the planting calendars when supplying federal credit to farmers. The Agricultural Zoning has helped farmers to use proper technologies, protect the soil and the environment, plan their activities, decrease the production costs and risks and increase the national production and productivity. Figure 6 shows the copy of a screen that is one of the many maps produced by this project.

Yield Prediction - Development of models based on satellite and meteorological data for monitoring the yield of soybean, coffee and sugarcane fields. Figure 7 shows an example of the use of NDVI images to predict yield in sugarcane mills (see section 5 for more on usage of NDVI images to this purpose).

Absolute satellite calibration: - Research in this area is being conducted within a scientific cooperation program with INPE to perform the in-flight absolute calibration of the CCD/CBERS-2 camera (China-Brazil Environmental Remote Sensing Satellite) using a reference surface located in the northeast of Brazil. Figure 8 shows a photo of field data collection within this activity

Use of NOAA/AVHRR images in agricultural applications: - CEPAGRI has more than 25.000 NOAA/AVHRR images stored that were received by an acquisition equipment installed in 1994 and updated in 2004. The main use of these images is the monitoring of agricultural fields. Figure 9 shows the antenna installed at CEPAGRI to receive these images.

5. Research at the Institute of Computing – tools and techniques for remote sensing applications

Research on geoprocessing and remote sensing at the Institute of Computing is conducted within LIS – the Laboratory of Information Systems. The most recent projects within this domain involve cooperation with the Faculty of Agriculture Engineering and CEPAGRI (see sections 3 and 4). The Lab also cooperates with the center of Informatics for Agriculture of EMBRAPA (the Brazilian Ministry of Agriculture Research Center) and INPE (Brazil National Institute for Space Research). These cooperating partners provide domain knowledge, generate data and help validate solutions proposed by the computer scientists. Computing faculty, on the other hand, contribute with specific tools, techniques and methodologies that combine research from the fields of databases, image processing, software engineering and interface design. LIS at present has 1 post doctoral fellow, 9 PhD and 12 MSc students working in different kinds of computer science research. Ten other faculty members participate in the lab's research effort, most of which are computer scientists. There are also 10 undergraduate students attached to the lab, to help software development activities.

From 1997 to 2004, the Institute was awarded a special grant under the Brazilian Government Center of Excellence program, to develop research concerning advanced information systems for applications in agriculture, with emphasis in remote sensing data and technologies. Examples of results obtained under this context include a set of tools for managing and supporting decision processes in environmental management // new algorithms for content based retrieval, based on texture features, for satellite images// efficient image classification methods for SAR radar images // and novel database indexing and storage procedures for managing large collections of remote sensing data.

WebMaps (see also section 3) is an ongoing project coordinated by LIS that exemplifies the multidisciplinary cooperation that is typical of remote sensing projects within UNICAMP. It is financed by CNPq (the Brazilian

National Research Council) and is jointly developed with the LABGEO lab of the Faculty of Agriculture Engineering (see section 3) and CEPAGRI (see section 4). Its goal is to provide, via Web, an integrated software platform to support formulation, implementation and evaluation of agriculture planning policies. This kind of goal requires combining research results in remote sensing and in distinct Computer Science domains. The remote sensing researchers work closely with their computing colleagues in distinct kinds of issues. For instance, work in databases and Web services is needed to allow efficient management and organization of large and heterogeneous data sources – not only satellite and radar images, but also land use, soil, climatological, and socioeconomic data. Image processing research is needed to design and develop new algorithms for feature extraction and content-based retrieval. Software engineering faculty contribute by specifying and developing domain-specific software, as well as designing appropriate testing procedures. Interface design researchers work at supporting multiple interaction modes, and distinct user profiles and modalities.

Figures 10a and 10b show an example of work conducted within WebMaps and that is going to be made available on the Web until July 2005. It computes NDVI variation values for temporal series of MODIS (Moderate Resolution Imaging Spectroradiometer) images from the Terra satellite, thereby giving users an idea of the behavior of crops in a given region. Users enter, via Web, the coordinates of a region of interest, and a time period. The system then accesses an image database containing hundreds of images, to select the images corresponding to the period. They are then processed to determine the region within the images and, finally, the average NDVI value for the region is computed over the image series. The result is displayed online. The database contains images from the south of Brazil (MODIS quadrant h13v11) and resolution is 250m x 250m per pixel. Figure 10a shows part of one satellite image, where the square outlines the region selected by the user, corresponding to the area around Barretos county in Sao Paulo state. Figure 10b shows the temporal evolution of the average pixel value within this region, over a period of four years.

6. Education initiatives

Two undergraduate and two graduate degrees in the University require knowledge of remote sensing basics. The University also offers a continuing education course in Geoprocessing. Finally, the authors and their colleagues supervise MSc and PhD work in the area. Undergraduate degrees in agriculture engineering and in geosciences require analysis and management of satellite and radar imagery. Students have hands-on training in different projects, and cooperate with graduate students in their activities.

Both the Institute of Geosciences and the Faculty of Agriculture Engineering offer graduate degrees where students can direct their research to remote sensing issues. Examples of these defended can be found at the authors' lab Web sites. Finally, the Institute of Computing hosts a continuing education course in Geoprocessing (360 course hours) for professionals from government agencies and private institutions. Half of the credits are taken in computing subjects (e.g., databases, networks or software engineering) within the context of georeferenced and remote sensing data management and applications. The other half involve different aspects of RS technology and algorithms. Three of the authors coordinate the course, and all authors participate in its teaching activities.

REFERENCES

The reader is referred to the sites of each lab mentioned in this paper, where references to publications and further examples of work conducted can be found.

LIS - Institute of Computing – www.lis.ic.unicamp.br

CEPAGRI – www.cpa.unicamp.br

LABGEO – Faculty of Agriculture Engineering – www.agr.unicamp.br

LAPIG – Institute of Geosciences – www.ige.unicamp.br

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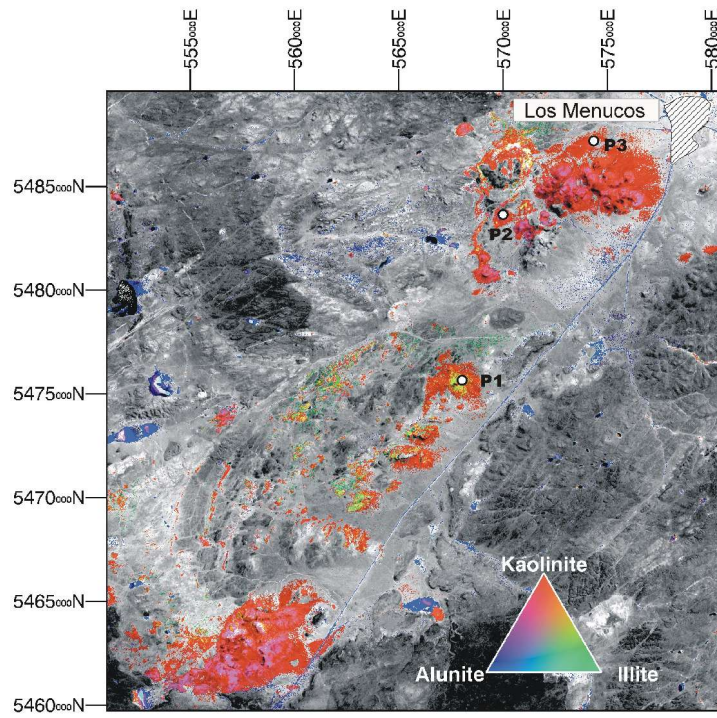


Figure 1. Principal component analysis applied to alteration mapping using ASTER (Los Menucos district, Patagonia, Argentina)

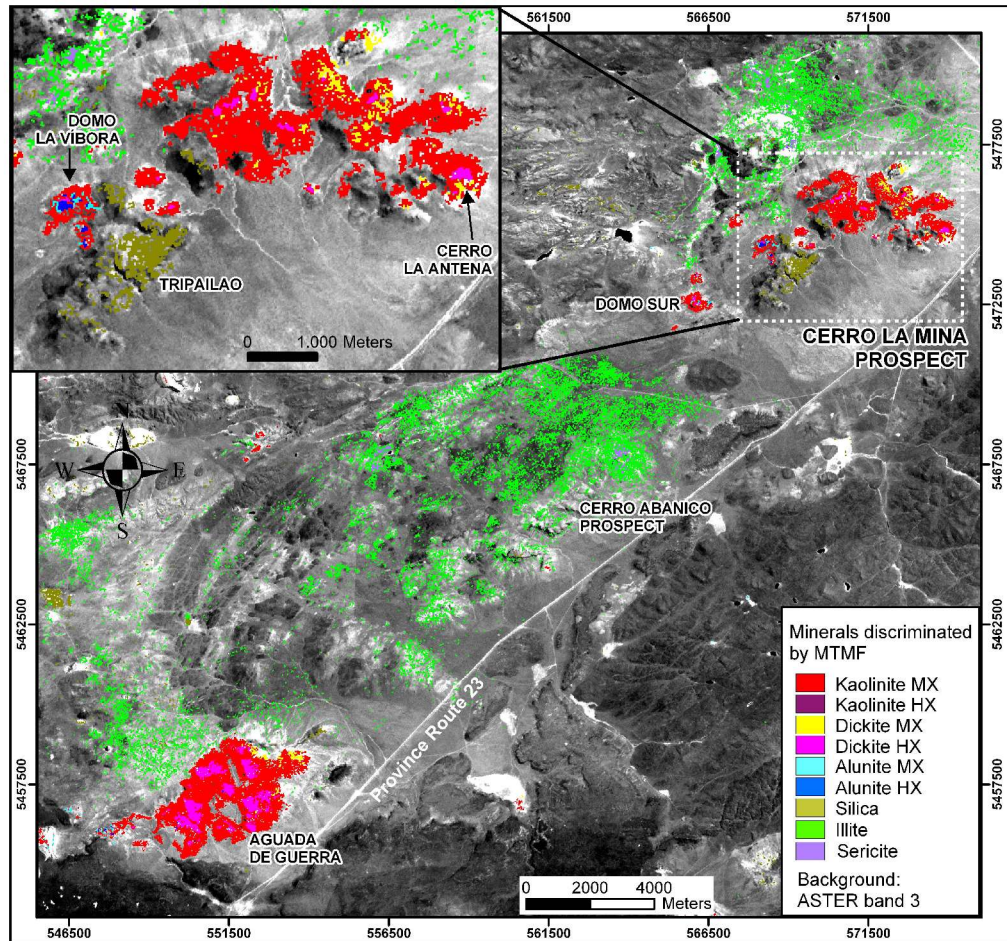


Figure 2. Mapping alteration minerals for gold exploration using hyperspectral classification on ASTER imagery (Los Menucos district, Patagonia, Argentina).

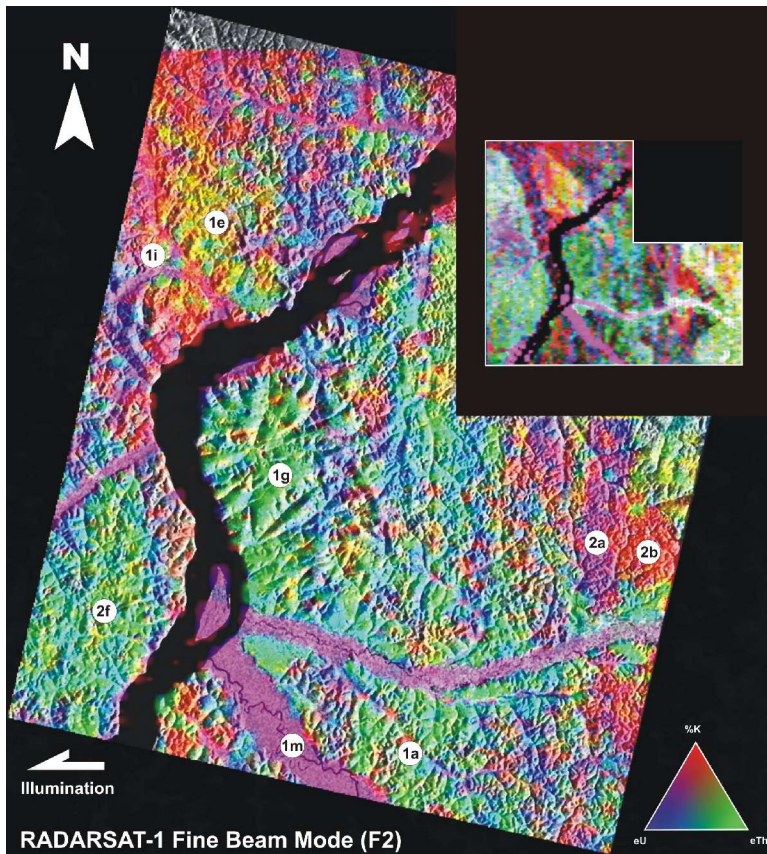


Figure 3. Intensity-Hue-Saturation integrated image of gamma-ray and RADARSAT-1 Fine Mode (F2) data, covering an area in the Tapajós Mineral Province (Amazon). Potassium (%K), thorium (eTh) and uranium (eU) are expressed in red, green and blue hues, respectively. Inset: RGB colour-composite image of the radioisotopes %K, eTh e eU, respectively. Such product has been integrated to airborne magnetic data and yielded a detailed geologic map with key geologic units (units 2a and 2b) that proved to be associated to gold occurrences in the Province.

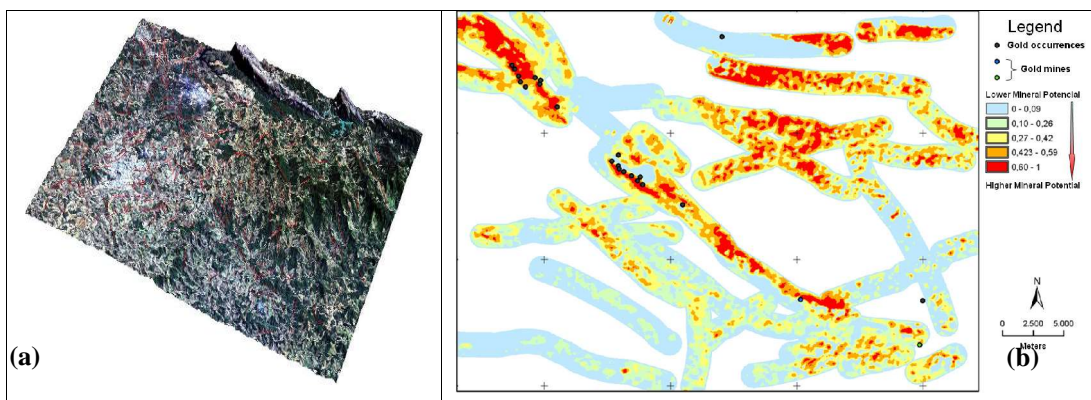


Figure 4. (a) Perspective view of a portion of the Iron Quadrangle (SE Brazil) portrayed by an ASTER multispectral imagery (bands 3,2,1 - RGB) merged with a digital elevation model derived from ASTER stereoscopic bands. (b) Mineral potential map for gold in the Iron Quadrangle derived through ArcSDM algorithms.

Scaling up information on crop monitoring

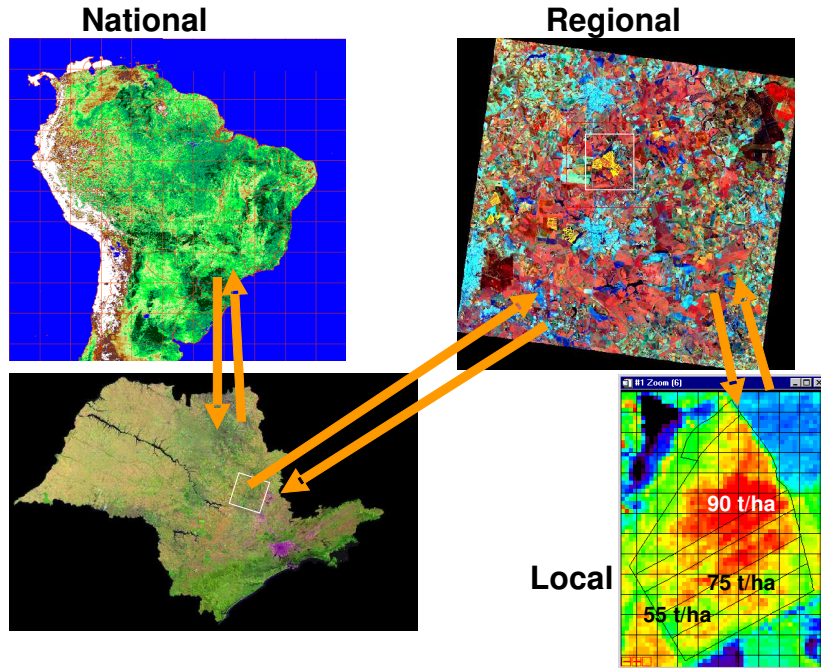


Figure 5: Scaling up information in crop monitoring is a key research topic at LABGEO

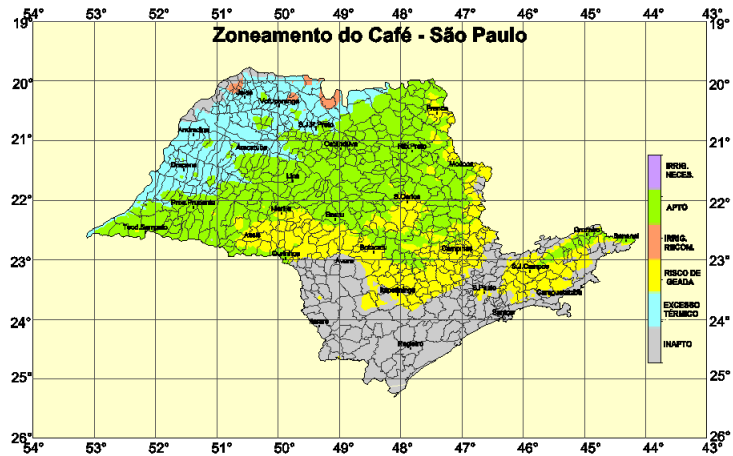


Figure 6: Agricultural Zoning for the Coffee in the State of São Paulo

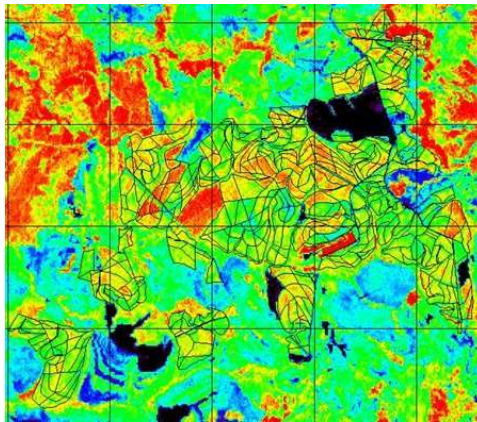


Figure 7: NDVI variability to guide yield prediction in sugarcane mills



Figure 8: Field data collection campaign to calculate the calibration coefficients for Cbers 2 (China-Brazil Environmental Remote Sensing Satellite)



Figure 9: NOAA/AVHRR antenna at CEPAGRI

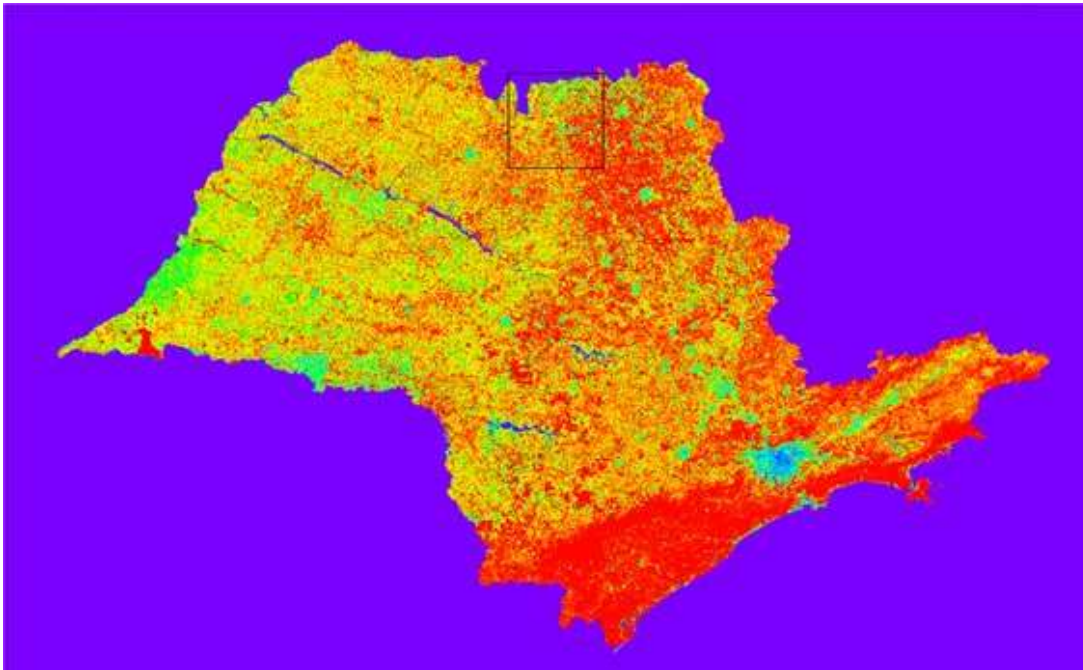


Figure 10 a) Area extracted from MODIS image, Sao Paulo state, Brazil- region within square (Barretos county) shows area where user asked for NDVI profile temporal series analysis

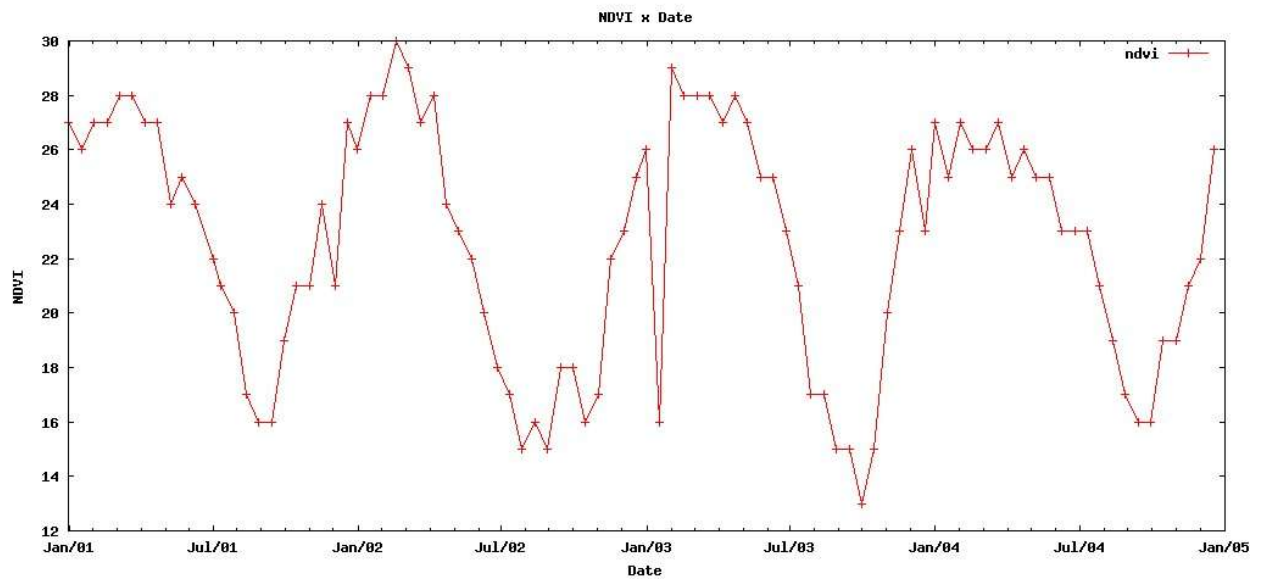


Figure 10 b) Temporal data showing NDVI value evolution within the delimited region