

Mapping the Central Corridor of the Brazilian Atlantic Rainforest

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Abstract

Brazil is experiencing phenomenal growth and with it comes the pressure on the environment from agricultural and urban expansion. Today only fragments remain of the once exuberant Atlantic Rainforest (Mata Atlântica). In an effort to save the fragments and develop a management plan, our team was asked to map the region at a scale of 1:100,000 identifying land use and vegetation and integrating data from specialists. The study area is the central region of the Atlantic Rainforest and stretches from Salvador, Bahia, to the border of Espírito Santo with the state of Rio de Janeiro. Our mapping effort is part of a larger project that aims to establish an updated set of geographic data to support a management plan for the study area. This paper will present the project, the goals and the issues involved in creating and integrating the various physical and demographic GIS data layers.



Fig.1 – Coastal Atlantic Rainforest: Island of Boipeba, Bahia – Brazil
(source: public domain photo)

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1. Introduction to the Atlantic Rainforest (Mata Atlântica)

The Amazon region is well known for its biological diversity and general importance to the health of our planet. However, Brazil has other areas with great biological importance. Historically, thousands of kilometers of Brazilian coastline were covered with vast tropical forests that stretched far inland. Today only fragments remain of the once exuberant Atlantic Rainforest (Mata Atlântica), while the pressure to destroy what is left continues at an accelerated rate.

1.1 - History of the Forest

The Atlantic Rainforest evolved over millions of years, stretching across the vast coastline and far inland of what is now Brazil. When Africa separated from South America, the subsequent erosion of the huge alpine mountain chains left from the continental collisions provided conditions for evolution of the vegetation that became the Atlantic Rainforest. With an area of 1.3 million km², this was once the home to not only a huge diversity of plants and animals, but to thousands of native peoples as well. It was second only to the Amazon Basin.

The process of deforestation and fragmentation began with the arrival of the Portuguese explorer Pedro Álvares Cabral in the year 1500. The colonists became especially interested in exporting the “Pau Brasil” (Brazil Wood) tree, which had diameters similar to North American redwoods (now almost extinct). The first contact between Brazilian Indians and Europeans took place in the coastal region of the Atlantic Rainforest, what is now “Porto Seguro, Bahia”.

The capital of the state of Bahia, Salvador (our base of operations), was founded in 1549, opening the floodgates to the slave trade and vast plantations. As “civilization” expanded, other activities such as mining and fishing also began to take their toll. However, the principal threat to the forest remains the rapid expansion of farming and ranching activities, often clearing land through poorly controlled burning. Over 70% of the Brazilian population lives within the biome of the Atlantic Rainforest. Especially in the Northeast of Brazil, vast sugar cane plantations contributed significantly to the fragmentation process. Today eucalyptus, cocoa, coffee, soybean, beans, bananas, coconuts, and ranching activities play a key role in this region. What was once only forest is also



Fig. 2 16th century map of Northeast Brazil (EAC-SP)

occupied by several huge urban centers with populations ranging from 2 million to 11 million, with interstate roads interconnecting them. According to Câmara (1991), the original fragments of Atlantic Rainforest visible today add up to an area of only 8% of the forest area existent at the time the Portuguese began colonization. Recent, unconfirmed information indicates that less than 3% of the original forest actually remains in 2005.

1.2 - Fragmentation

The total area of the Atlantic Rainforest is now less than 50,000 sq. km, and in fragments. Fragmentation of the Atlantic Rainforest can be understood as the degree of separation between individual forest landscape groups which were initially continuous (METZGER, 2003). The fragments are left after human activity devastates large portions of the forest cover, leaving odd shaped islands clearly visible from satellite such as Landsat, Spot or the Brazilian/Chinese CBERS. This process of fragmentation also isolates fauna and flora, endangering species in the region. Many fragments are small and lack interconnection. A few fragments are large and in fact have been designated as protected areas. However, simply designating the area as protected is ineffective. Especially in the less developed north of Brazil, local corruption and lack of federal and state policing lead to severe infraction of existing environmental law. Unregulated farming and ranching, illegal logging and uncontrolled urban expansion all continue as if no laws existed. The situation calls for the application of satellite mapping and an integrated GIS to aide in protecting and managing this precious resource of importance not just to Brazilians, but to all of humanity.

2. The CCMA Project and Study Area

In an effort to save the fragments and develop a management plan to connect them in “corridors”, our team was asked to map the region at a scale of 1:100,000 identifying land use, vegetation and integrating data from specialists in biology, sociology, economics, oceanography, fisheries and forestry.

Our mapping effort is part of the project “Corredor Central da Mata Atlântica” (CCMA) which aims do establish an updated set of geographic data to support a management plan for the study area. It is a sub-project of a larger project, Corredores Ecológicos (Ecological Corridors) funded by GTZ/PNUD, and managed by the World Bank and the Brazilian Ministry of the Environment.

The Ecological Corridors Project hopes to protect Brazil's biodiversity by creating ecological corridors in two of the most important areas, the Amazon and the Atlantic Rain Forest regions. Specific objectives include creation and expansion of protected areas, prioritizing connectivity; support for environmental monitoring and sustainable use of natural resources in the corridor areas; consolidation of monitoring systems; implementation of corridor management plans; and implementation of sub-projects in interstitial areas.

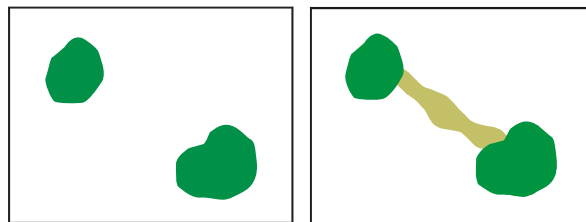


Fig. 3 – Connecting Fragments to create interconnecting corridors

A variety of incentives and regulations may be used to increase the size of protected areas and the areas connecting them. The project also seeks to improve the management and protection of existing national, state, municipal and private protected areas and stimulate the creation of additional public and private protected areas within the corridors.

The project also aims to increase the connectivity of forest cover between protected areas by promoting the conversion of private lands into conservation areas, supporting sound resource management and rehabilitating local communities in strategic locations, as well as formulating policy recommendations that provide economic incentives for conservation.

The project will seek to coordinate these actions through participatory and decentralized project management that encourages cooperation among federal, state, and municipal government agencies, research institutions, community, civil society organizations, and private landowners. Scheduled to be a five-year project, it focuses on two large rain forest corridors. One area is in the central Amazon, encompassing 245,500 sq. km, the other area (see Fig. 4), in the northern Atlantic Rainforest, measuring 77,500 sq. km.



Fig.4 – Map showing our final project area (red) on land and in the ocean. Includes the southeastern portion of the state of Bahia and the entire state of Espirito Santo, Brazil.

Project Sponsors and Participants:

- PNUD
- GTZ
- World Bank
- Ministry of Environment (MMA)
- the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA)
- State environmental agencies
- Project units collaborating with public and private stakeholders
- NGO's and community groups.

Financing:

The US\$39.65 million over-all project is financed by the Rain Forest Trust Fund, the German government, the European Commission and federal and state government counterpart funds. Technical support is provided by the German Technical Cooperation Agency (GTZ). The mapping and thematic information collection portion of the project utilized a little over US\$ 1.2 million for both the Amazon and the CCMA.

Staff:

The mapping team consisted of a Senior Land Use/Cover interpretation expert familiar with the region, a senior ArcGIS specialist to establish data processing procedures, a GIS assistant for general data processing, a remote sensing specialist to organize and perform classification routines on the Landsat images, and the Project Manager as team leader, task manager and technical guide for advanced procedures.

Equipment:

Our lab was equipped with a total of 5 computers. Each a Pentium 5 with 256 of Ram and 120 Gb HD. All had an off-board video configuration for better visualization performance of the Landsat scenes integrated with vector data. Each had a 19" monitor. They were connected in a local network, isolated from the main network, but retaining internet access.

3. Remote Sensing and Classification

Landsat 7 images (30 meter resolution) from times between 2001 to 2002 were purchased from ENGESAT covering an area of 12 adjacent scenes (fig. 5). Due to problems with cloud cover, it was necessary to purchase additional scenes upon arrival of the team in Salvador. Also already purchased were 12 duplicate scenes with bands 5,4,3 fused with the panchromatic band, increasing the spatial resolution for visualizing and identifying features.

To avoid spectral confusion, the original non-fused bands were used during the classification process. All images are in a Geotiff format. Upon arrival to our office in Salvador, Bahia, the images were converted from UTM – Zone 24 (Corrego Alegre datum) to UTM – Zone 24, (SAD69 - South American datum 1969), southern hemisphere. This was done to insure compatibility with the main geographic databases in several Brazilian agencies, especially IBGE (Istituto Brasileiro de Geografia e Estatística), which defines most geographic standards for Brazil.

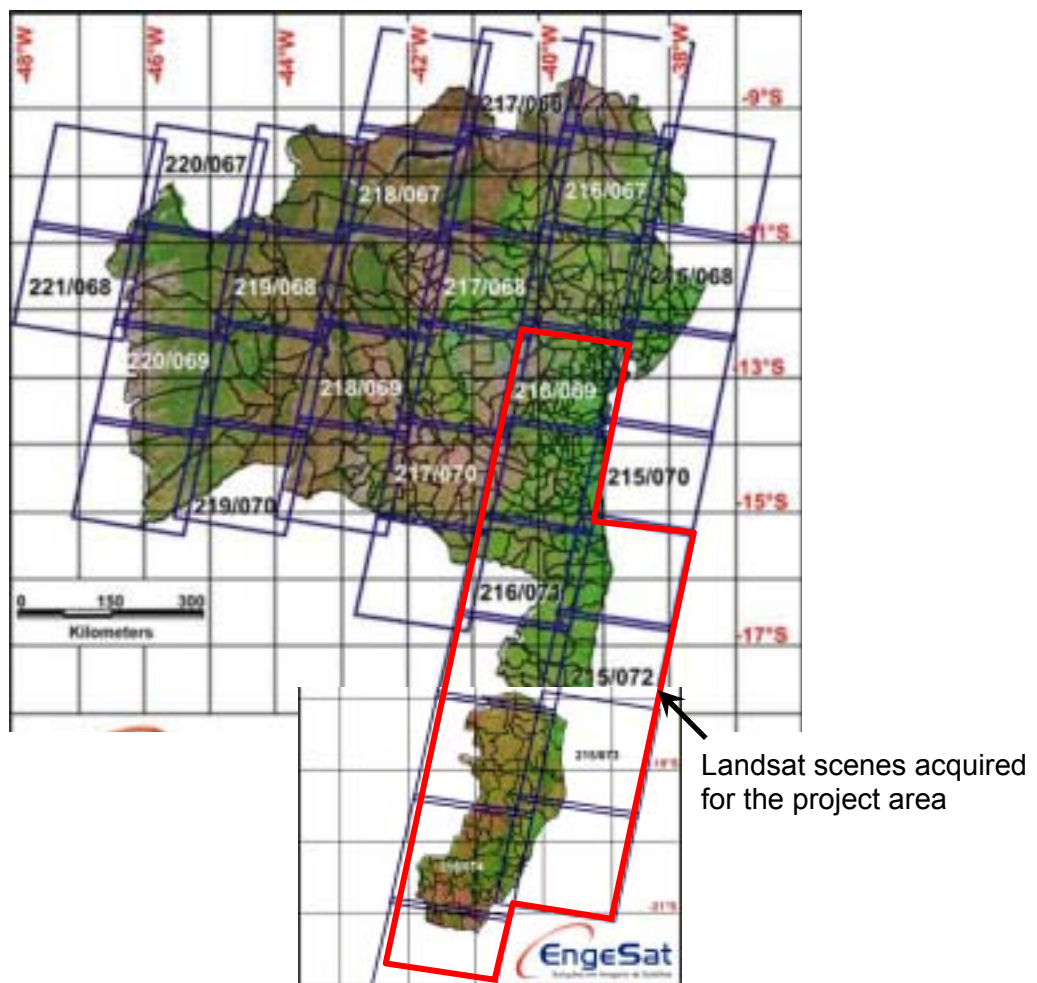


Fig. 5 – Area designated in red delineates the individual Landsat 7 scenes purchased for the project. Source: ENGESAT

3.1 - Integrating Images with Vector Data

We utilized ArcMap as the main visualization and data integration tool. Initial visualization of the images was performed using the virtual mosaic capability, making background values in the Landsat images transparent. Histograms and pyramids were also built for each image, making visual enhancement and browsing easier. Vector data such as municipality polygons (example below, Fig. 6), road network, hydrographic features and elevation contours were overlaid to help guide the visual identification of features.

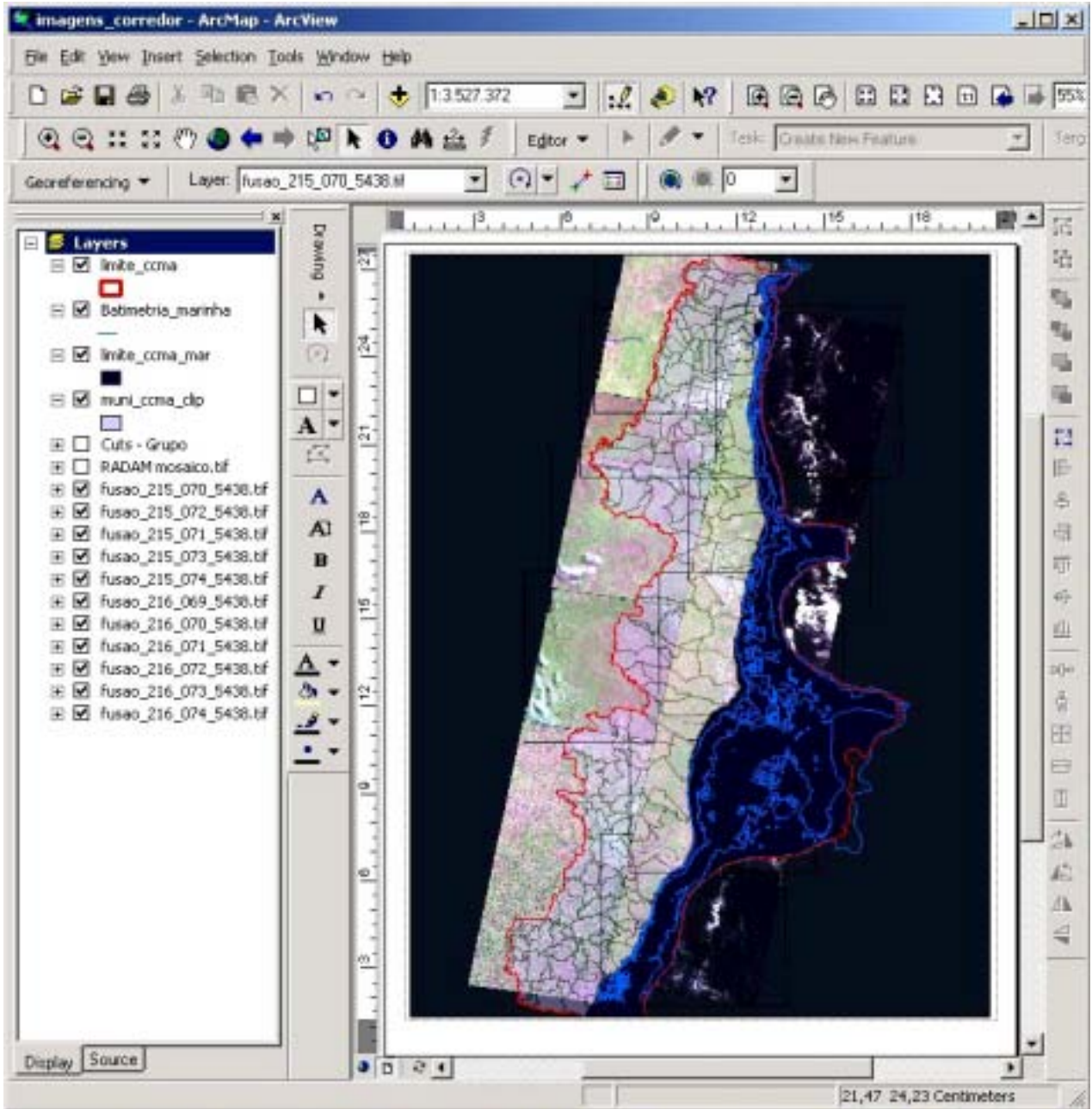


Fig. 6 – Georeferenced Landsat images in a virtual mosaic. Final project area – red outline, Municipal Boundaries – black polygons, Depth Contours – blue lines.

3.2 - Defining the Study Area Boundary Polygon

The study area boundary is of great importance, since it defines where future environmental and social project funds can be applied. In fact, much of the conflict that persists between NGO's and the consortium came not only from competition for the funds for developing the management plan and performing the mapping, but also in wanting to define the boundary area in such a way that their projects would be guaranteed. Until the team in Salvador began work, the issues surrounding definition of this polygon paralyzed the consortium management, which had little experience with mapping projects.

There were actually two boundaries created by our team that were merged into one. One was for the land area and the other for the oceanic region up to the edge of the continental shelf. The northern land limit (fig. 7 below) was initially established to be the northern limit of the hydrographic basin of the Jequiçá River, which marks a transition area to a drier climate. It was later extended to include additional forest areas to the north of the basin limit (see figures 4 and 6 for final boundary maps). The southern and southwest limits are the boundaries of the state of Espírito Santo.

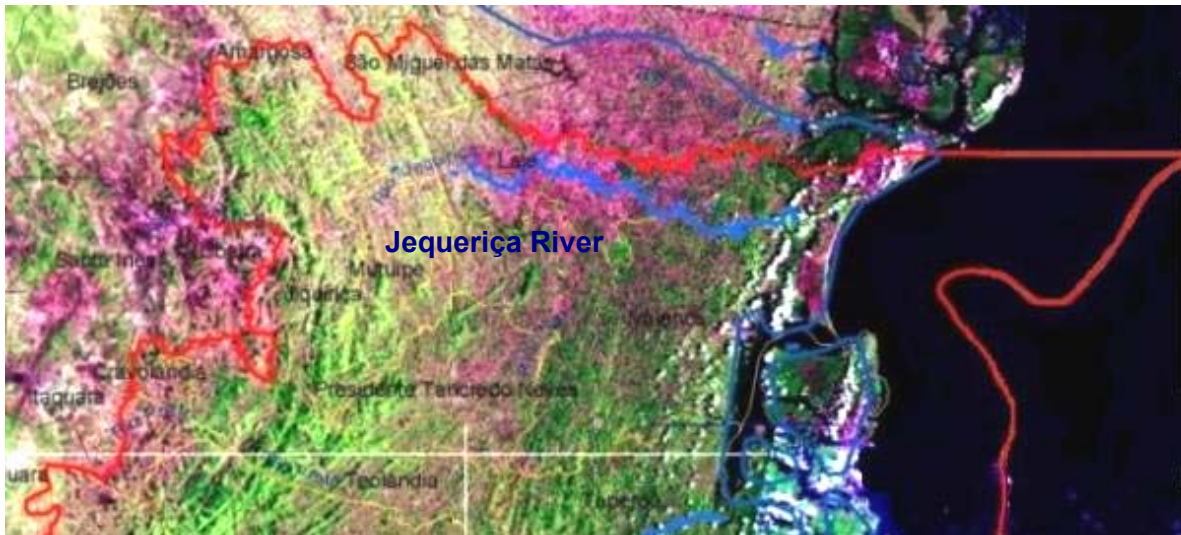


Fig. 7 – Northern boundary defined in the north by the Jequiçá Basin and in the west by the Dense Ombrófila Forest Landsat/Radam definition. The boundary in the ocean is defined by the 200 m depth contour and continues following this line until the southern limit in Espírito Santo.

Early in the project it was established that the northwest portion of the CCMA project area boundary would be defined according to the type of vegetation cover present. The defining vegetation was designated to be the Dense Ombrófila Forest (Primary & Secondary). This is usually associated with old growth forests or forests at an advanced stage of regeneration, characterized by a dense canopy structure and needing a relatively humid climate.

The previous team in Brasilia spent months waiting for a forestry consultant to define the northwest border through field observations and image interpretation, while other consultants (specialists in biology, geology, etc.) went into the field, researched the literature, and in some instances acquired subject specific geospatial information. This caused a great deal of confusion, since specialists were being forced to work with a changing definition of the northwest portion of the boundary. For this reason some early maps differ from later maps in this region, and were thus scheduled for later updating. In

fact, the boundary was not completely defined up until the day that our team in Salvador took over. Upon arrival we decided to resolve the situation quickly, making the trip to the mid region of the study area in the Atlantic Rainforest to meet with the forestry specialist, and define a strategy. The forestry specialist and I jointly decided to scan the Radam¹ maps, which have a clear definition of Dense Ombrofolia Forest boundaries, but at a scale of 1:1,000,000. Our team then registered this to the UTM-24, SAD69 projection and digitized the line using ArcMap. This vector line was then overlaid on the Landsat images, which were used to refine the line according to the interpretation of the forestry specialist and myself (fig. 8 a & b). The task was completed in 2 weeks.



Fig. – 8a. Western border of the study area as defined by maps from the Radam Project, the dividing line being the transition from Dense Ombrofolia to other types of forest or land cover.

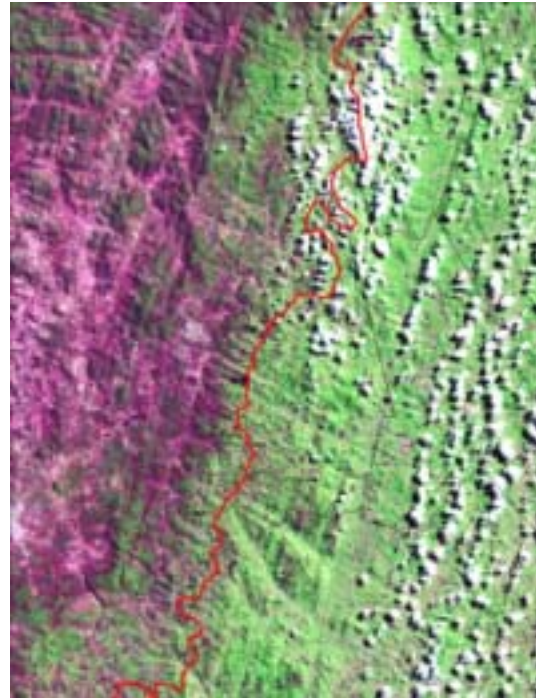


Fig. – 8b. Border line defined from the Radam map overlaid on the Landsat image of the same area. Though vegetation can be seen extending beyond the boundary, it is not of the same type, belonging to a drier climate.

¹. The RADAM project began in the 1970's and utilized Radar images and aerial photos to create the first and last comprehensive vegetation map of the Brazilian territory. Considering the changes over time, general transitions coincide.

3.3 - Classification

The Landsat images were processed using ENVI software which was used for reprojection, spectral analysis and classification. It was also utilized for masking operations utilizing Shape file polygons generated in ArcView.

Realizing early that classifying entire scenes would introduce too much spectral confusion, we decided to sub-divide each scene according to the distribution of cover types and environmental domains. Note for example, the differences between coastal and inland areas in the figure below (Fig. 9). Within ArcView, polygons were generated to delineate the cut boundaries. Note that some overlap was intentionally left between mask areas to insure that no zero values would be accidentally introduced with the final mosaic of the classification results.

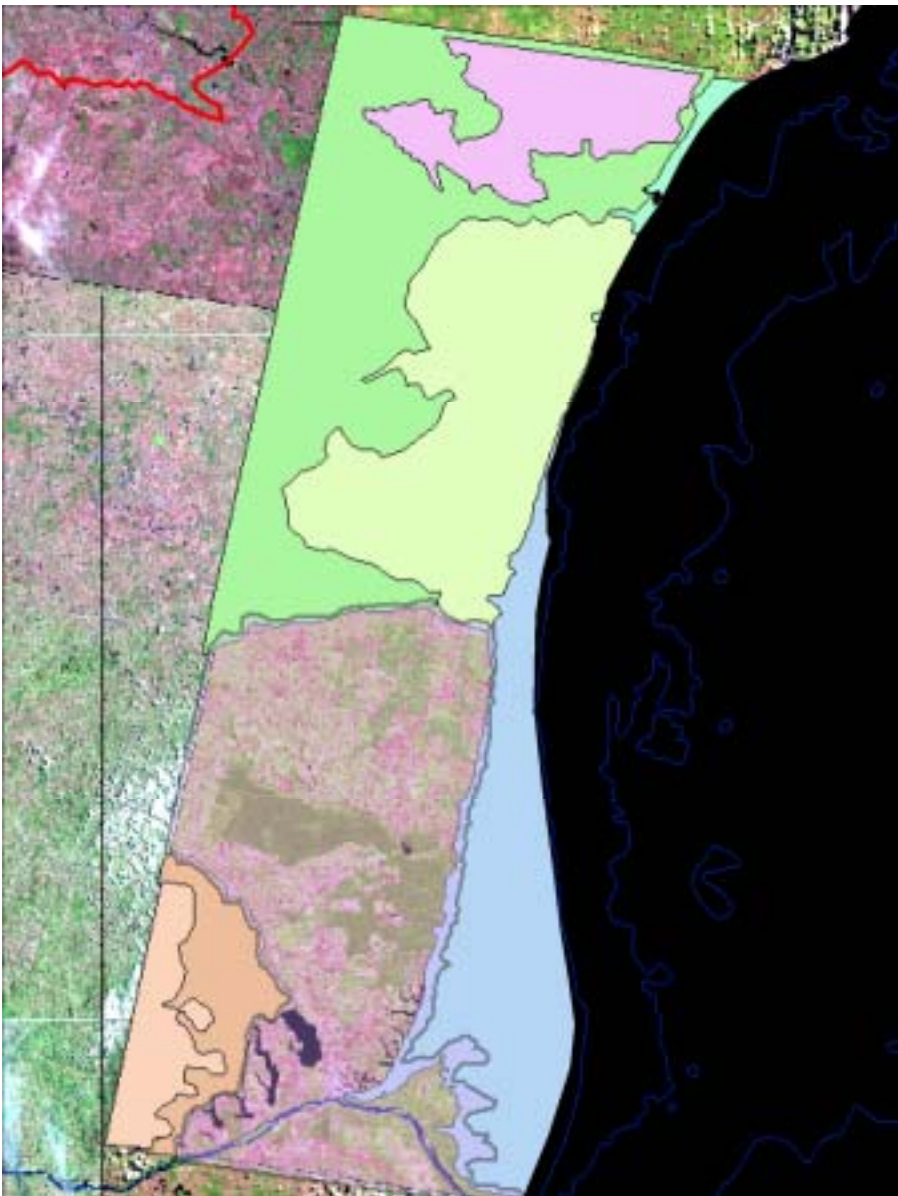


Fig. 9 – Landsat scene 215-073 of Northern Espirito Santo with polygons defining areas to separate for classification, avoiding spectral confusion.

Each image was cut into various sections using the polygons, creating new images with zero values for all pixels beyond the mask area. In this way we were able to isolate potentially troublesome classes. Collecting training samples was also made easier by this process. Our challenge was to perform the supervised classification over a relatively large area that had a mix of spectrally similar cover types. This is why the strategy of dividing up the images into sub-regions before applying the Maximum Likelihood algorithm proved successful.

Earlier, selected test classifications were used to understand the pattern of spectral confusion. The scenes chosen were representative of the various cover types present. Each Landsat image was then analyzed visually, with auxiliary overlays, looking for cover types that might have problems remaining separate from each other during the classification process.

Tests were also performed using principle components analysis and NDVI, comparing these to the 6 non-thermal Landsat bands. None of these procedures provided superior separability of the classes of interest and were thus not utilized. For the cover types present in the images, the band combination 5, 4, 3 proved most useful in separating the potential classes. An early test was performed using the unsupervised ISODATA algorithm. However, as suspected, the amount of confusion led us to choose a supervised approach. Test classifications were performed using Spectral Angle Mapper (SAM) and Maximum Likelihood using the same spectral sample areas. Since additional bands did not separate the spectral classes any better, only bands 5,4,3 were utilized for the final classifications. These performed well using the Maximum Likelihood algorithm applied to the masked areas.

This situation of spectral confusion is especially true in regions with tropical vegetation. To map such a region using Landsat data, remote sensing experience is important, but in this case, extensive image interpretation experience with these specific cover types was needed. Given a limited choice of consultants with mapping experience, and even less with GIS skills, we chose to focus on someone with extensive field and image interpretation experience to guide the effort. This person (Dr. Rodolfo Vega) was a specialist in soils and formerly a key player in the largest mapping project ever performed for Brazil, RADAM, over 20 years ago. Though lacking experience with computers and GIS, we were successful in training him on how to perform basic operations with ArcView. Points were defined corresponding to the legend items, and Dr. Vega used this to digitize cover type and land use identifications interactively. The resulting point Shape file was then transferred through the local network to the specialist performing the Land Use/Cover with the masked Landsat images. These, along with GPS based field information, and basic roads, rivers, elevation and municipal data provided support for choosing spectral samples.

Operational Legend - prepared by Dr. Rodolfo Vega e Danilo Sette (forester)

■ Natural Landscape

- ◆ Lowlands, Submontana, Montana, Altimontana
 - Dense Ombrófolia Forest (Primary, Secondary)
 - Open Dense Ombrófolia Forest
 - Alluvial Ombrófolia Forest
 - Stational Semi-deciduous Forest (Primary, Secondary)
 - Stational Deciduous Forest
- ◆ Mangroves
- ◆ Restinga

- ◆ Wetlands
- ◆ Mussunungas (circular depressions)
- ◆ Altitude Fields
- **Transformed Landscape (Degraded area)**
 - ◆ Ranching
 - Grazing Land (natural, planted, abandoned, degraded)
 - Flood plains (áreas alagadas)
 - Land being prepared for ranching
 - ◆ Agriculture
 - Temporary (Corn, Beans, Mandioc root, Rice, Pineapple)
 - Permanent (Coffee, Mamão, Sugar Cane, Banana, Coconut, Red Palm Oil, Citrus)
 - Land being prepared for agriculture
 - ◆ Forest Cultivation (Cocoa/Cabruca, Seringa, Eucalyptus, Pine)
 - ◆ Mixed Use (Pasture, Agriculture & Cultivated Forest)
 - ◆ Urban
 - ◆ Other Uses
 - Aquiculture
 - Degraded Areas
 - Extractive
 - Mining
 - Roads
 - ◆ Special Areas
 - Conservation Units
 - Rural placement
 - Indigenous Lands
 - Military areas

Continuous cover types and very large rivers were designated as part of the raster data sets to be produced with the classification. Smaller rivers, roads, townships and similar data types remained as vectors to be overlaid over the raster. At a later stage, the plan was to homogenize the raster land use and vegetation data and convert the two maps to vector.



Coastal / Mangroves



Grasslands/ Wetlands



Forest / Pasture



Cabruca (cocoa plantations)



Eucalyptus Plantations

Source for images: Danilo Sete

3.4 - Classification Results

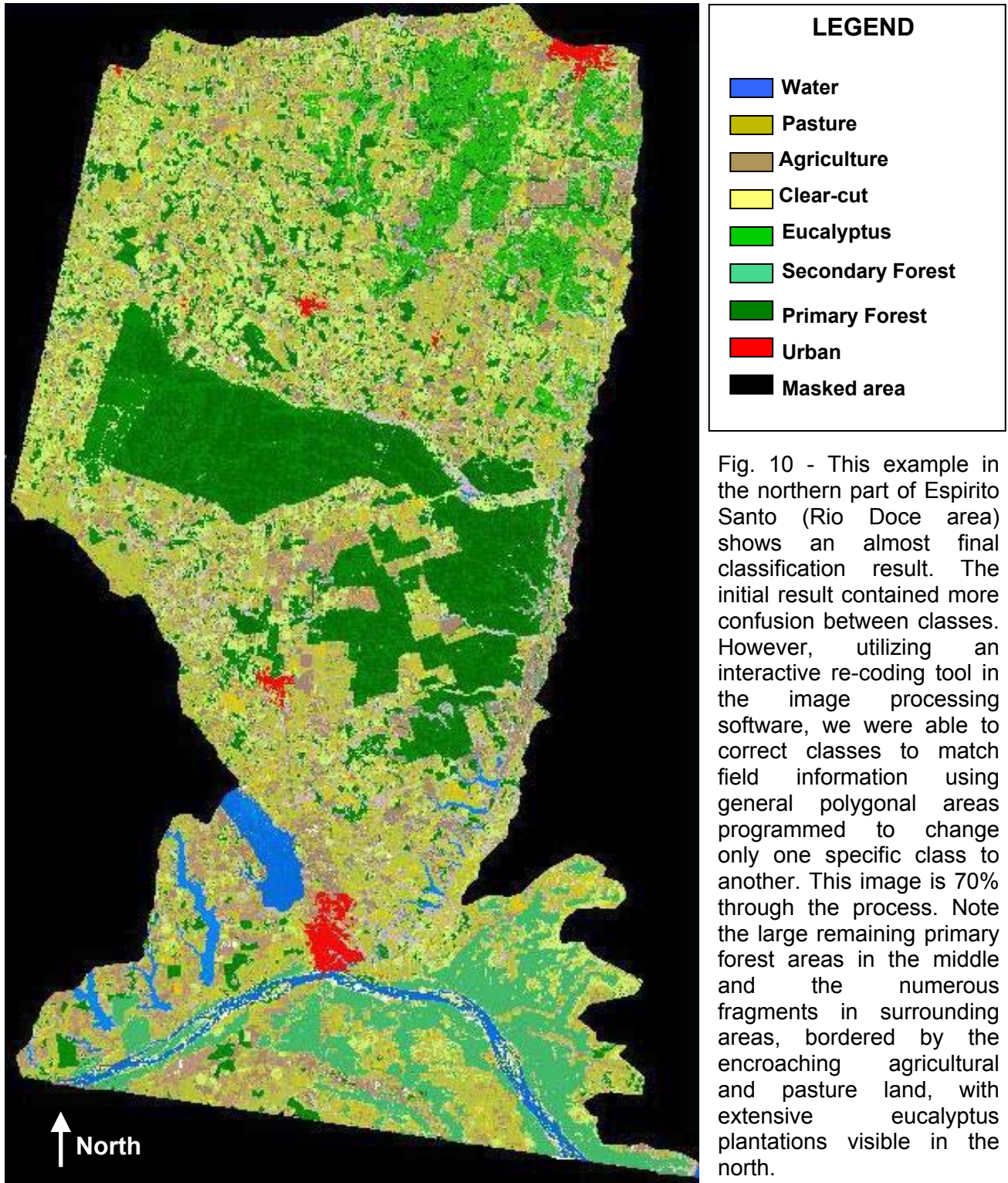


Fig. 10 - This example in the northern part of Espírito Santo (Rio Doce area) shows an almost final classification result. The initial result contained more confusion between classes. However, utilizing an interactive re-coding tool in the image processing software, we were able to correct classes to match field information using general polygonal areas programmed to change only one specific class to another. This image is 70% through the process. Note the large remaining primary forest areas in the middle and the numerous fragments in surrounding areas, bordered by the encroaching agricultural and pasture land, with extensive eucalyptus plantations visible in the north.

Post classification corrections were first applied to each isolated sub-region, while visually comparing to adjacent classifications. The sub-regions were then mosaiced ignoring zero values. Transition areas were checked for discontinuities. All performed as overlays on the original Landsat images and integration of the point data to avoid misclassification.

4. Evidence of Deforestation

Though not on the official list of items to specifically map, in the course of analyzing the Landsat images we discovered obvious evidence of deforestation (fig. 11). The image below shows several stages of the process of clearing land for agriculture, and how it often erodes the edges of protected forest areas.

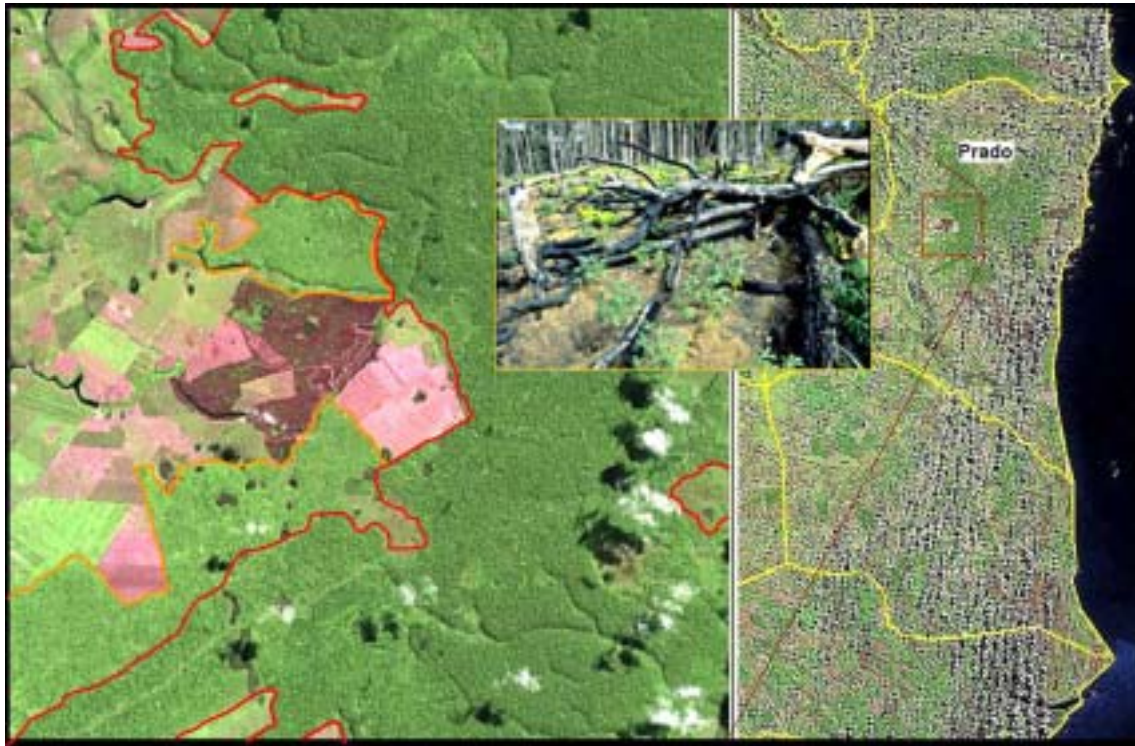


Fig. 11 – This area in the extreme south of Bahia, municipality of Prado (Landsat 7, scene 215-071) shows the clearing of land for farming by burning (darker, purple areas). The adjacent pink areas were cleared earlier and are in an advanced stage of preparation for planting. The darker green forested area (red boundary) is a theoretically protected area. The light green forest regions (orange boundary) are what is known as secondary forest, regenerating after having been cut down in previous years.

Illegal logging activity as well as this type of forest clearing for agriculture or pasture is the driving force behind the destruction of the Atlantic rainforest. In addition, each time a new road is introduced that runs through the forest area, the rate of destruction multiplies in a capillary manner. Though the government designates specific areas as protected, it does not place an adequate number of people in the field, nor has it made good use of satellite images, leaving it up to local municipal governments to fend for themselves. A reality of Brazil is that most rural municipalities are governed by mayors who buy their votes through special favors. This activity includes granting illegal concessions to clear land to friends and family members. With the current boom in agricultural exports, there is a race to acquire and clear land as soon as possible, with government incentives to do so. It is common to burn forests ignoring even the potential value of the wood. The only requirement, which is often ignored, is to leave at least 20% of forested areas on their land untouched. Due to poor salaries, lack of training, and long standing social issues, even environmental inspectors visiting an area have a tendency to succumb to the bribes offered by the local land owners to look the other way. There have been cases of well intentioned inspectors being maimed or even killed in the process of gathering evidence.

5. Data Collection and Integration

Supporting data included IBGE census statistics and the following auxiliary vector layers:

- Main Roads
- River, streams and lakes
- Elevation Contours
- Towns
- Mountain ranges
- Municipal boundaries
- Limit of the study area (see section 3.2)

5.1 - Data Acquisition

- The digital maps for the state of Bahia were obtained in the form of DWG quad sheets from SEI – “Superintendência de Estatística e Informação”, a statistical division of the state government of Bahia.
- The quad sheets for “Espírito Santo” were obtained in DGN format from the website of IBGE “Instituto Brasileiro de Geografia e Estatística”, the Brazilian federal organization that conducts the census and maintains the statistics and geographic database for the country.

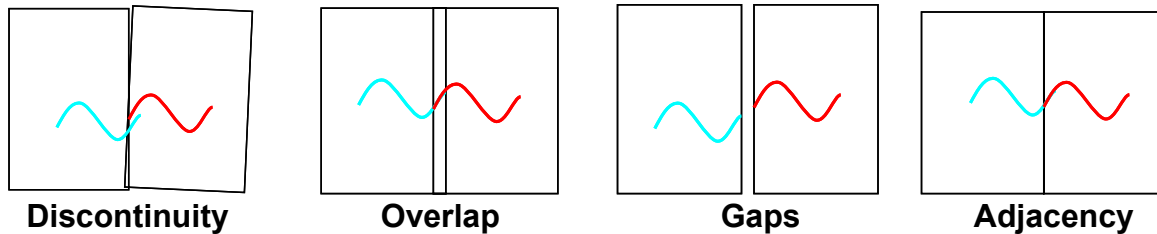
We acquired 56 quads at a scale of 1:100,000, 42 in Bahia and 14 for the north of Espírito Santo, and 34 quads at a scale of 1:50.000 for the south of Espírito Santo. All were converted to the Shape file format and reprojected to UTM, zone 24, SAD69. These layers consisted of hydrography, elevation contours, roads, and towns.

The data was organized in the following manner:

Theme	Field	Attribute
Rivers & Streams	Name	River name
	Type	Permanent, Intermittent, Island, Coast Line, Canal, Lake, Estuary...
Elevation	Name	Altitude value
	Type	Master line, Intermediate line
Towns	Name	Location name
Roads	Name	Road name
	Type	Paved road, Bridge, etc.

Unfortunately, though the IBGE compilations were produced between 2002 and 2003, the individual data layers displayed problems typical of quad sheets produced from different sources at different times. IBGE collects data from various sources to integrate, but does not make itself responsible for correcting data errors nor edge matching problems. Thus before joining each quad into a single mosaic for the study area, the integrity of each data layer was checked. We also analyzed edge matching issues, correcting them as necessary.

Below are some of the problems encountered and corrected.



Besides the basic quad maps, various thematic data sets needed to be converted to geographic form. In some cases information remained in text or tabular format for lack of a “geographic link”. Since our team arrived after the biologists, economists and other specialists had already been in the field, we were forced to accept what we had. In cases where some form of geographic link (such as the name or code of a municipality) existed, we cleaned the data and imported the attributes into an existing attribute table (Fig. 12).

	A	B	C	D
1	Cod_ibge	Município	Estado	
2	2900603	Aguara	BAHA	
3	2900801	Alcobaca	BAHA	
4	2900900	Almadina	BAHA	
5	2901007	Amargosa	BAHA	
6	2901957	Aparema	BAHA	
7	2902252	Arafaca	BAHA	
8	2902401	Aurelino Leal	BAHA	
9	2902906	Barra do Choça	BAHA	
10	2903102	Barra do Rocha	BAHA	
11	2903300	Barro Preto	BAHA	
12	2903409	Belmonte	BAHA	
13	2903706	Boa Nova	BAHA	
14	2904308	Brejões	BAHA	
15	2904704	Buararema	BAHA	
16	2904803	Caatiba	BAHA	
17	2905404	Cairu	BAHA	
18	2905602	Camacan	BAHA	
19	2905800	Camamu	BAHA	
20	2906303	Canaveiras	BAHA	
21	2906907	Caravelas	BAHA	
22	2908002	Coaraci	BAHA	
23	2909605	Craolândia	BAHA	
24	2910008	Dário Meira	BAHA	
25	2910305	Élseo Medrado	BAHA	
26	2910404	Encruzilhada	BAHA	
27	2910727	Eunápolis	BAHA	
28	2910909	Firmino Azeis	BAHA	
29	2911006	Floresta Azul	BAHA	
30	2911204	Gandu	BAHA	

Fig. 12 – Municipality codes and names associated with municipal polygons. Due to some data sets having spelling differences for the same municipality name, we chose to create the link to import subject matter specific attributes using the Cod_ibge (IBGE municipal code) when possible.

In other cases we received point data from the field in the form of Excel files (species occurrence data). Some of these contained Lat/Lon coordinates and related names and

attributes with thousands of entries. The various data layers we were tasked with creating/integrating consisted of:

- Land use
- Vegetation
- Urban area polygons
- Demographics (population, income, etc.)
- Agricultural production statistics
- Fishing activity off the coast
- Rivers and streams
- Lakes
- County polygons
- Roads
- Railroads
- Contour lines
- Geology
- Coastline and ocean geology
- Coral reefs
- Bathymetry to 200m
- Species occurrence

As explained previously, the land use and vegetation maps had to be created with the support of satellite images. We also integrated geologic, coral reef and fisheries data for the ocean area inside the study area polygon. The goal is to use these data layers in an integrated manner to support environmental management decisions. On land, besides implementing a management plan, the main goal is to identify forest fragments and establish potential models to connect them creating “ecological corridors”. The various data layers will also support the policy decisions that will have to be negotiated with local land owners, county/state governments, NGO’s and local citizens.

The specific areas of study for the project included:

- Forestry
- Biology
- Geology
- Hydrography
- Oceanography
- Economics
- Sociology
- Anthropology/Archeology
- Political organization

Our team was tasked with integrating the data from these studies, in some cases having no information to link a specific observation to a geographic location. We thus separated non-geographic information from those with at least an association with a municipality. The biologic data, which included species distribution, arrived with the necessary coordinate information to create a point Shape file (see section 5.3). Most of the geologic and oceanographic data arrived in an ArcMap compatible format, already in a map form that could be reprojected (if necessary), cleaned up, and organized with the other layers. We also integrated HDI (Human Development Index) and other maps from the PNUD Atlas, which provides municipality level statistics for every state in Brazil.

5.2 - Physical and Oceanographic Data

The physical data for the study area included geology, soils, elevation, slope, and climate. See the below (fig. 13) and the appendix for a few examples of these and oceanographic maps.

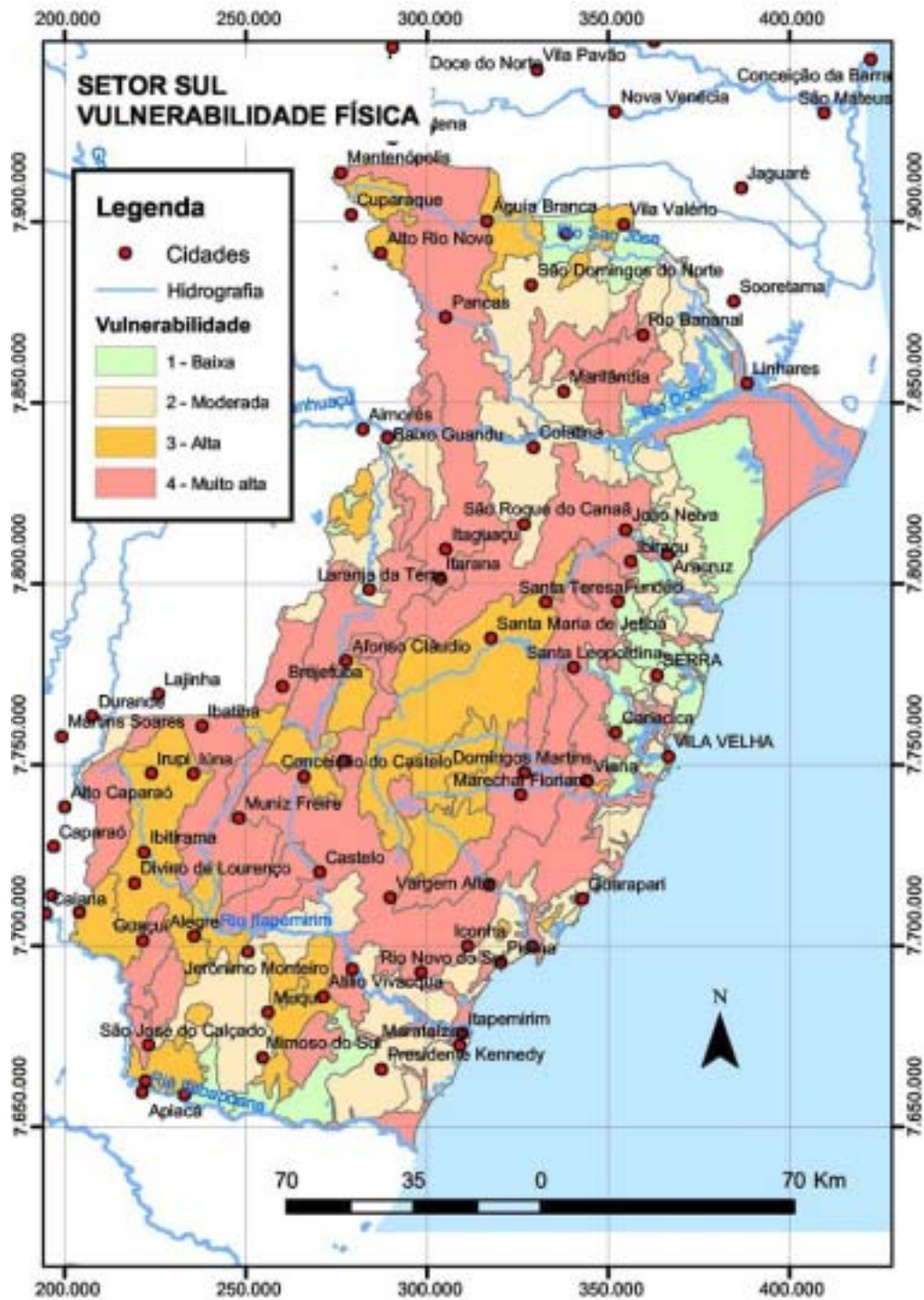


Fig. 13 – This map of the southern most part of the study area, in the state of Espírito Santo, displays the relative vulnerability to environmental degradation of specific areas. Green is the lowest and pink is the highest vulnerability (Credit – Ronaldo Lyrio).

5.3 - Biological Data

The biological information for the project was collected from a variety of sources, including secondary field observation. By secondary we mean that due to time constraints the project researchers did not go into the field themselves to collect species location observations. They relied on published records and collaboration with organizations with ongoing research. Some information remained in the form of text and tables to be later linked in the database. Other information, specifically the species occurrence data, arrived in the form of Excel spread sheets (Fig. 14 below).

Point	Order	Genus	Species	County	Mun. do mu.	Long. (W)	Lat. (S)	Easting	Northing
Point 1	1.0000000000	Adelphophrynus	pachydactyla	BA	Ibicus	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 2	2.0000000000	Adelphophrynus	pachydactyla	BA	Ibicus	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 3	3.0000000000	Adenomera	boliviana	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 4	4.0000000000	Adenomera	boliviana	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 5	5.0000000000	Adenomera	boliviana	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 6	6.0000000000	Adenomera	hyalodactyla	BA	Una	-38.0752900000	-15.2933300000	491918.0000000000	8308222.0000000000
Point 7	7.0000000000	Adenomera	hyalodactyla	BA	Una	-38.0752900000	-15.2933300000	491918.0000000000	8308222.0000000000
Point 8	8.0000000000	Adenomera	hyalodactyla	BA	Una	-38.0752900000	-15.2933300000	491918.0000000000	8308222.0000000000
Point 9	9.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 10	10.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 11	11.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 12	12.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 13	13.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 14	14.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 15	15.0000000000	Adenomera	raimonata	BA	Rabuna	-38.0454400000	-14.7888900000	494679.0000000000	8365017.0000000000
Point 16	16.0000000000	Adenomera	raimonata	BA	Una	-38.0752900000	-15.2933300000	491918.0000000000	8308222.0000000000
Point 17	17.0000000000	Aparasphenodon	brunsi	ES	Aracruz	-48.2733300000	-19.8202800000	366643.0000000000	7607896.0000000000
Point 18	18.0000000000	Aparasphenodon	brunsi	ES	Aracruz	-48.2733300000	-19.8202800000	366643.0000000000	7607896.0000000000
Point 19	19.0000000000	Aparasphenodon	brunsi	BA	Canavieiras	-38.5472200000	-15.6750000000	505656.0000000000	6267087.0000000000
Point 20	20.0000000000	Aparasphenodon	brunsi	BA	Canavieiras	-38.5472200000	-15.6750000000	505656.0000000000	6267087.0000000000
Point 21	21.0000000000	Aparasphenodon	brunsi	ES	Conceição da Barra	-38.7322200000	-18.5933300000	422746.0000000000	7944804.0000000000
Point 22	22.0000000000	Aparasphenodon	brunsi	ES	Conceição da Barra	-38.7322200000	-18.5933300000	422746.0000000000	7944804.0000000000
Point 23	23.0000000000	Aparasphenodon	brunsi	ES	Conceição da Barra	-38.7322200000	-18.5933300000	422746.0000000000	7944804.0000000000
Point 24	24.0000000000	Aparasphenodon	brunsi	ES	Guaapari	-48.4875000000	-20.6666700000	344010.0000000000	7714815.0000000000
Point 25	25.0000000000	Aparasphenodon	brunsi	ES	Guaapari	-48.4875000000	-20.6666700000	344010.0000000000	7714815.0000000000
Point 26	26.0000000000	Aparasphenodon	brunsi	ES	Linhares	-48.0722200000	-19.3911100000	367409.0000000000	7855538.0000000000
Point 27	27.0000000000	Aparasphenodon	brunsi	ES	Linhares	-48.0722200000	-19.3911100000	367409.0000000000	7855538.0000000000
Point 28	28.0000000000	Aparasphenodon	brunsi	ES	Linhares	-48.0722200000	-19.3911100000	367409.0000000000	7855538.0000000000
Point 29	29.0000000000	Aparasphenodon	brunsi	ES	Linhares	-48.0722200000	-19.3911100000	367409.0000000000	7855538.0000000000
Point 30	30.0000000000	Aparasphenodon	brunsi	ES	Linhares	-48.0722200000	-19.3911100000	367409.0000000000	7855538.0000000000
Point 31	31.0000000000	Aparasphenodon	brunsi	BA	Nova Viçosa	-38.3719400000	-17.8919400000	460601.0000000000	8021723.0000000000
Point 32	32.0000000000	Aparasphenodon	brunsi	BA	Nova Viçosa	-38.3719400000	-17.8919400000	460601.0000000000	8021723.0000000000
Point 33	33.0000000000	Aparasphenodon	brunsi	BA	Ponte Segura	-38.0647200000	-16.4487200000	493091.0000000000	8181218.0000000000
Point 34	34.0000000000	Aparasphenodon	brunsi	BA	Ponte Segura	-38.0647200000	-16.4487200000	493091.0000000000	8181218.0000000000
Point 35	35.0000000000	Aparasphenodon	brunsi	BA	Ponte Segura	-38.0647200000	-16.4487200000	493091.0000000000	8181218.0000000000
Point 36	36.0000000000	Aparasphenodon	brunsi	ES	Presidente Kennedy	-41.0468700000	-21.0988900000	267298.0000000000	7625533.0000000000

Figure 14 – Point occurrence data for various types of amphibians found within the project study area in the Atlantic Rainforest

Using Excel to DBF conversion functions in MS Access, then accessing the file in ArcMap, we converted the species location data to point Shape files with attributes intact. Some were quite large, having several thousand entries. The point data were placed into the same map projection and integrated with complimentary data layers. Maps were produced for each species (see figure 15 on the next page). These included Amphibians, Birds, Ants, Mammals, Fish, and Reptiles.

Ocorrência de Espécie - Mamíferos

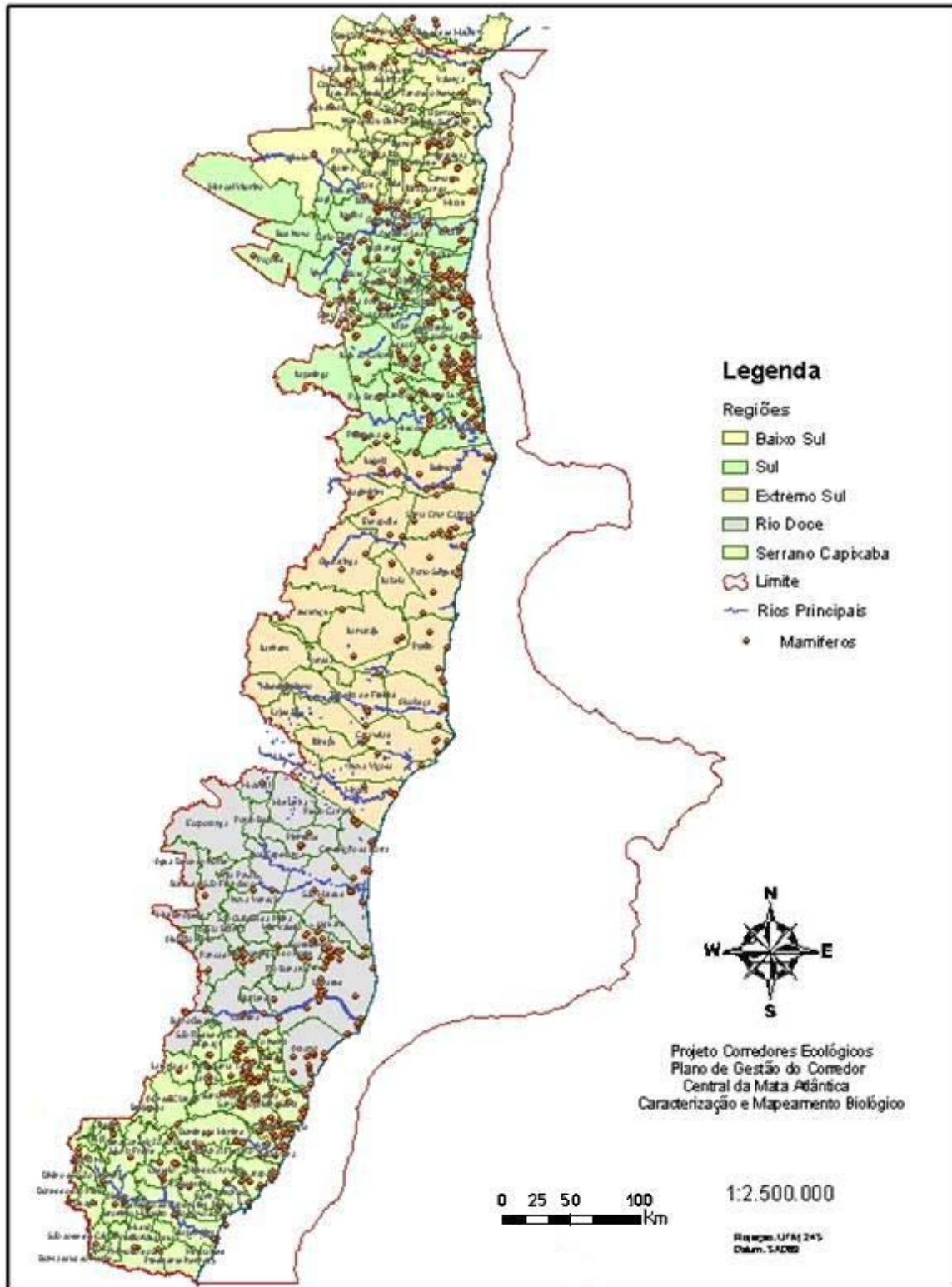


Fig. 15 – Map showing species distribution for the theme “Mammals”. Includes the entire project area at a scale of 1:2,500,000.

We did not write a script to perform the conversion task. The procedure we followed for converting the Excel species data tables is described below:

Converting Excel files to DBF using Microsoft Access

1. Open the Excel file from within MS Access
2. When the table options appear, select the specific table inside the Excel file (there are sometimes more than one)
3. Select the table and click advance until the end of the wizard.
4. The result is a DBF file containing the data from the table.

Importing the DBF to a point file by accessing the DBF using the Tools in ArcMap

1. Choose Add XYdata and open the DBF
2. Specify the fields for the X and Y coordinates
3. Specify the X and Y easting and northing
4. Using the right mouse button on the file, select Data/Export Data

We defined field names in cases where the tables arrived without these defined.

6. Map Products

There were several types of maps produced throughout the process, mostly in digital form. The PDF format was chosen for initial delivery of the maps (see appendix for a few examples).

Below is a list of some of the basic map products:

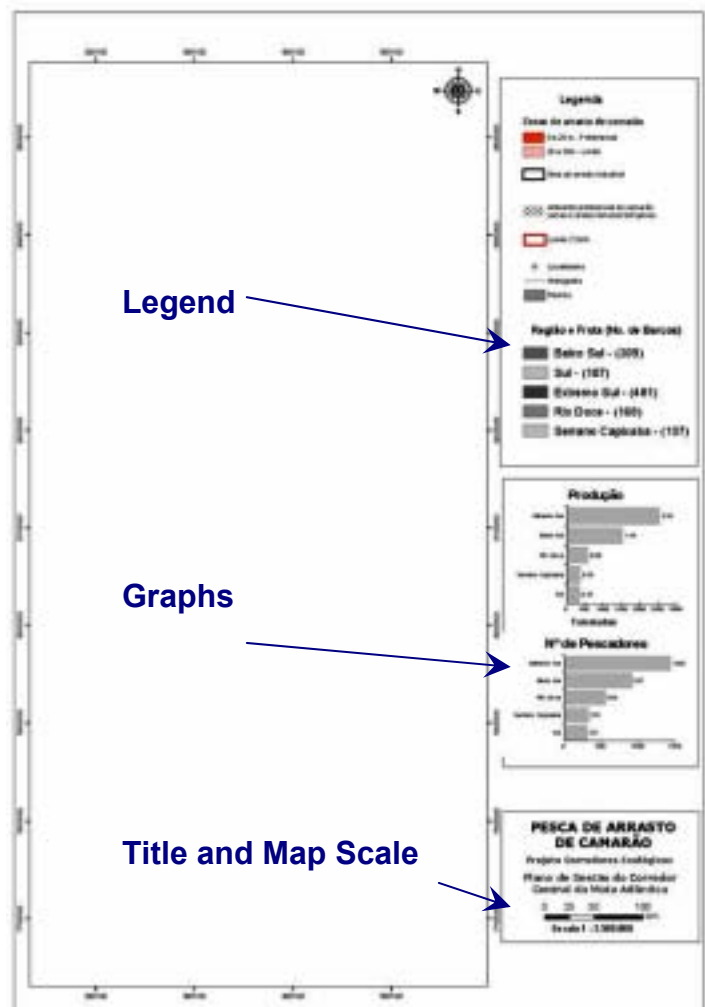
1. Image maps alone or integrated with vectors (whole area and specific sub-regions)
2. County (municipality) map up to the study area limit
3. Hydrography, roads, and population centers
4. Geology, soils, and erosion potential
5. Elevation contours and relief maps
6. Protected natural areas within the limit
7. Commercial and subsistence fishing activities compared to oceanic ecosystems
8. Study area limit and bathymetry
9. Land Use / Land Cover
10. Geographic distribution of species within the study area limits
11. Population by municipality and city

Some maps, such as Image Maps, were produced when the mapping process was just beginning. Since the final project area limit was dependent on part of the vegetation mapping, the northwest portion may display different municipalities, depending on when the map was produced. The plan is to re-do all maps before establishing the final data set with MXD files and PDF's. Map templates also evolved during the stages of the project, settling on the format in the example on this page.

Thematic maps showing fishing activity, demographic information, historical vegetation cover and species distribution were also produced while the Landsat classification process was taking place. Initial maps showed the entire area and were produced using a 1:2,500,000 scale. Subsequent maps were produced at a scale of 1:100,000 and 1:50,000.

The plan is to integrate all geographic information with the thematic tabular data in a database.

Finally, these data layers will be served to planners and consultants using a web interface.



7. Conclusions

This paper describes the situation of the Atlantic Rainforest, CCMA project issues, and the methodology our team applied to map the central corridor of the Brazilian Atlantic Rainforest. Though the mapping portion of the CCMA project had a difficult start in Brasilia, with establishment of the GIS mapping team in Salvador, the results described in this paper were achieved.

Our team was asked to establish a new lab in Salvador to collect and integrate data from various sources and thematic subjects, as well as creating the necessary land use / land cover data from supervised classification of Landsat satellite images. Specific tasks consisted of three distinct, yet integrated activities. The first activity was the preparation of the basic quads for the study area, which consisted of acquiring and integrating roads, hydrographic, elevation, and townships 1:100,000 and 1:50,000 quads. A final quad mosaic was produced for each at a scale of 1:100,000. The second activity was the processing and multi-spectral classification of Landsat images to produce the Land Use and Vegetation maps of the region. The third activity was the integration of the various subject matter specific geographic data layers (Biology, Geology, Hydrography, Oceanography, Fisheries, Economics, Sociology, Anthropology/Archeology, Political organization). This third activity extended to the integration of all other data in a single integrated data set at a scale of 1:100,000 (UTM zone 24, SAD69, Southern Hemisphere) in preparation for connection to a relational database and a web interface.

The results produced by the team in Salvador prove that the situation of the Atlantic Rainforest calls for the serious application of satellite mapping and an integrated GIS to aide in protecting and managing this precious resource. Illegal logging, agricultural expansion and municipal corruption have been the main factors in destruction and fragmentation of the Atlantic Rainforest. Moreover, the results also show that remote sensing and GIS talent is to be found in northeast Brazil, making it viable to put together a qualified group for this type of project using people from this region, avoiding the additional costs and potential problems of "importing" expensive consultants from the south. Brazil has a diversity of ecosystems, often lacking adequate mapping due to funding issues or poor use of existing data. Experience with the reality of a specific region and a strong desire to contribute are crucial elements in any mapping project, especially in this region.

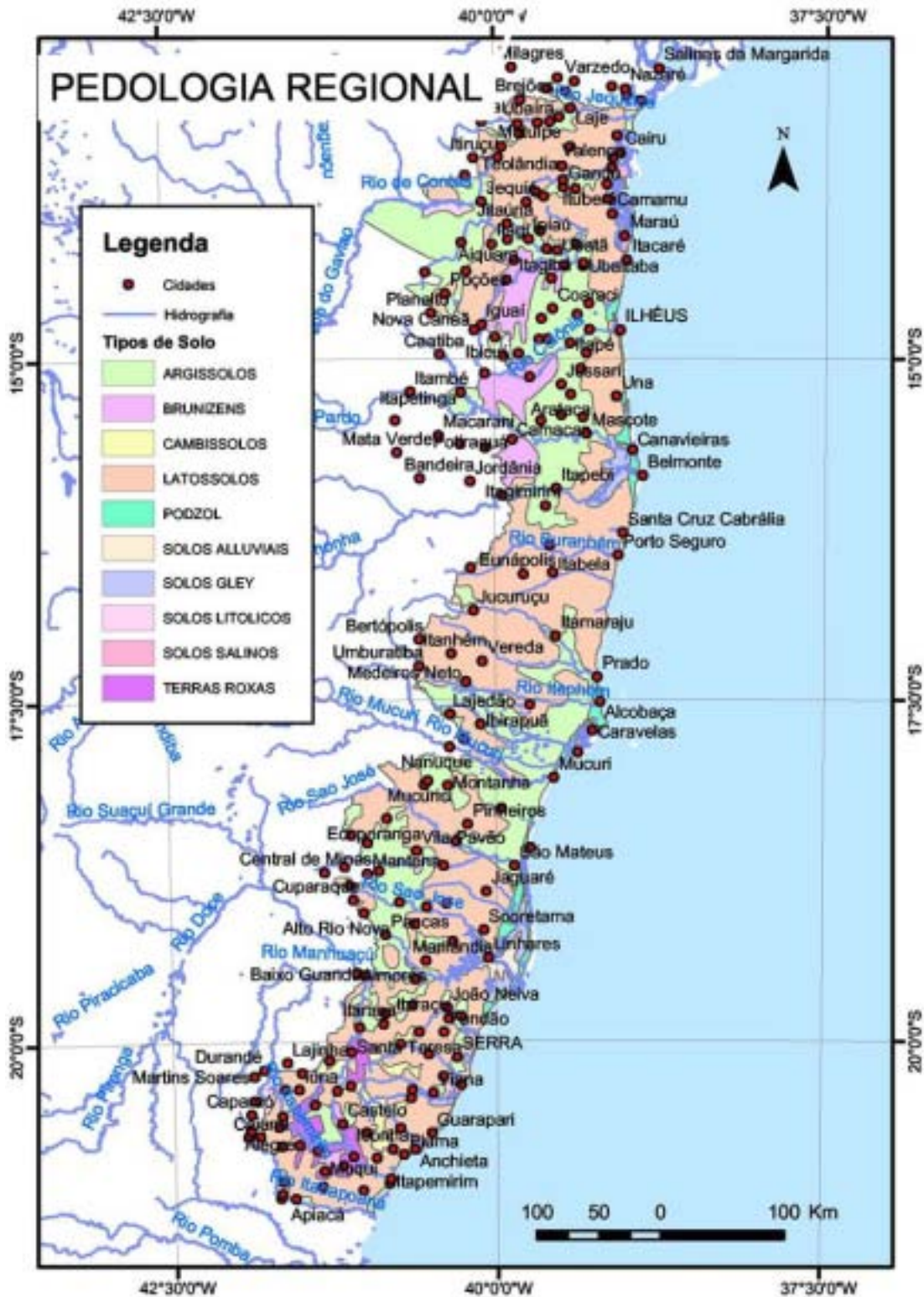
The data layers are close to their final form, and backed up, awaiting the decision to provide additional funding to complete the effort. The same status holds for the image classification process. This paper demonstrates the procedures and data layers produced as a part of this effort. Current negotiations between the consortium (TCBR, Funatura, Gopa) and the MMA/PNUD/GTZ will define the future direction of the project.

8. Acknowledgments

This paper is dedicated to my staff and to the people who believe we must try and save what is left of the Brazilian Atlantic Rainforest. I would especially like to acknowledge the hard work and dedication of the team, which produced great results in a fast paced environment, enduring delays in data acquisition, inappropriate data submission from field consultants, constant power outages, and complicated politics between NGO's, international agencies and the consortium. In particular, GIS Specialist Mr. Leonardo Euller applied his advanced ArcGIS skills to solve several data organization, conversion and map projection issues. Ms. Clea Cardoso quickly learned additional image processing skills, going on to apply advanced image processing techniques and multi-spectral land use / land cover classification with Landsat 7 data, while integrating reference point data and other vector layers. Ms. Camila Barreto was very efficient converting data, integrating additional quad maps, reprojecting data, and importing attributes. Our many thanks to Dr. Rodolfo Vega, well known for decades of experience mapping large areas of Brazil, who gave us a show on how to interpret and extract information from the images, making the Land Use / Cover mapping possible. I would also like to acknowledge the contribution of consultants Ronaldo Lyrio (Physical Geol.) and Dr. George Olavo (Oceanographic). All worked with utmost dedication and come highly recommended for future mapping efforts in any region.

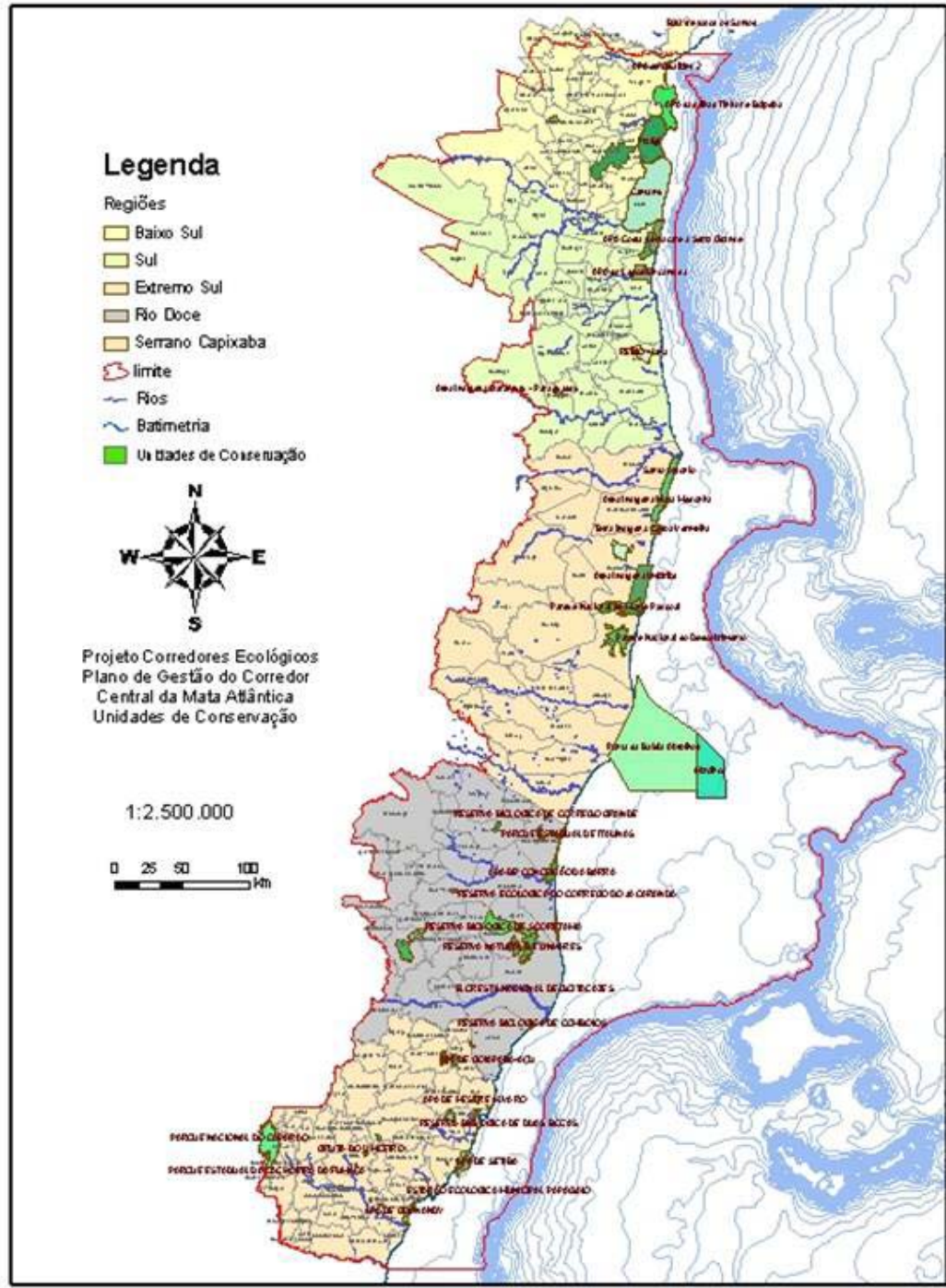
Thanks to the team for going beyond the call of duty and performing wonderfully!

9. Appendixes – Selected Maps

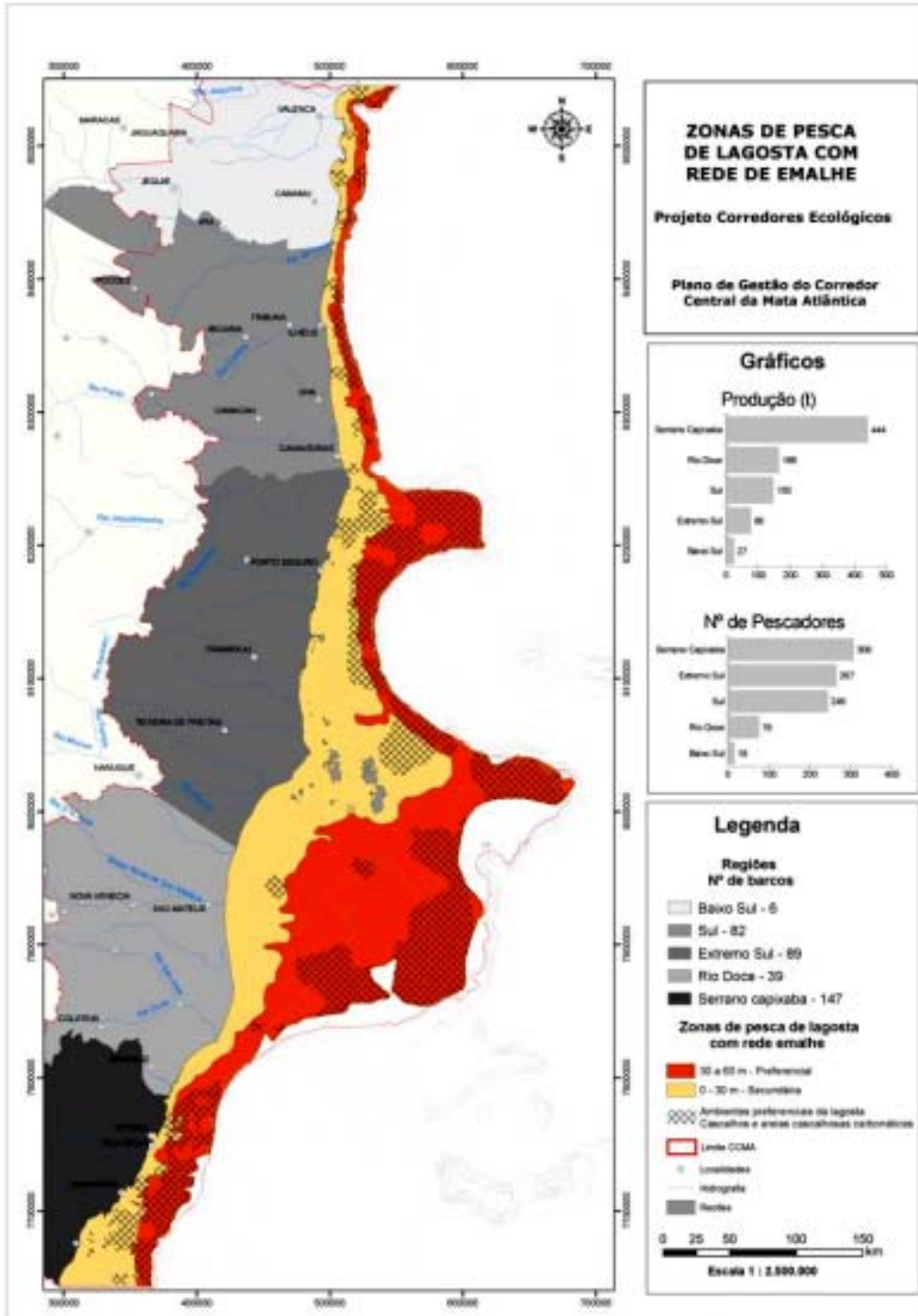


A1 - Soil types for the study area stretching from southern Bahia to the southern tip of Espírito Santo (Credit – Ronaldo Lyrio).

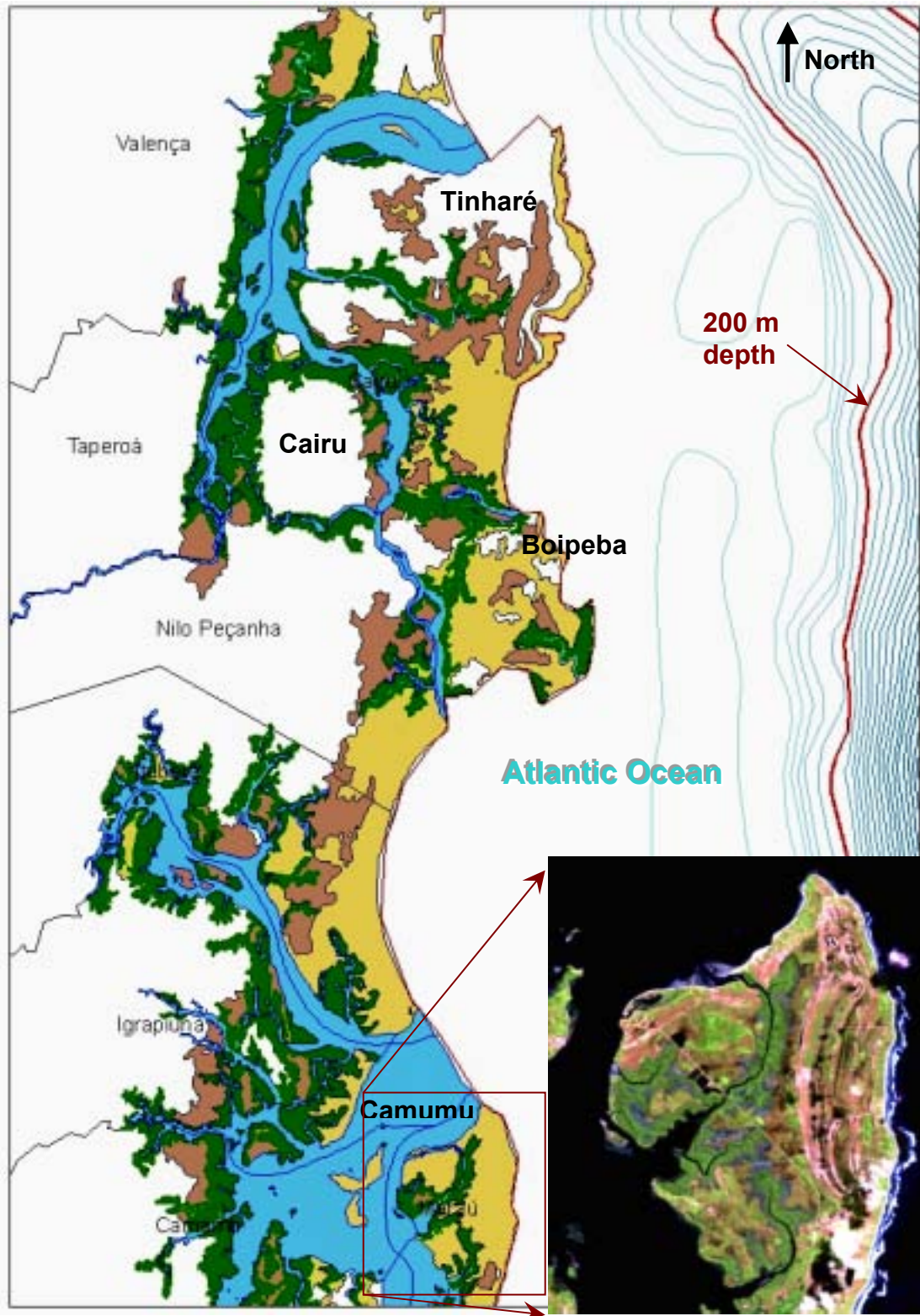
Unidades de Conservação - CCMA



A3 – Map of federal and state conservation areas on land and off the coast within the limits of the study area (finalizing the northwest portion of the limit did not introduce significant new conservation areas). Note the detailed bathymetry derived from Brazilian petroleum association. Divided by the 5 sub-regions (Lower South, South, Extreme South, Doce River, Serrano).



A4 - Lobster fishing zones utilizing nets. Legend shows number of boats corresponding to the 5 basic sub-regions of the project area (gray shades), net type (primary - orange, secondary - yellow), preferred lobster habitat (hashed areas), coral reefs (gray polygons in ocean portion of the study area). Credit – George Olavo and GIS team



A5 – Map showing mangroves (green) in the northern part of the study area. Large concentrations of mangroves can be found near the islands of Cairu, Tinharé, Boipeba, and the Camumu Bay. These are endangered from human activity. The Landsat-7 image of the Barra Grande peninsula in Camumu Bay shows detail of the area and mangroves.

10. Endnotes

Regional Cover Type Definitions:

***Restinga* forests**

A *restinga* is an ecosystem found on coastal plains containing vegetation adapted to the saline and sandy conditions, under the influence of tidal flooding, containing herbaceous species, arbustive vegetation and dense arboreal incidence. The estimate of *restinga* biomass was supposed in accordance with a survey conducted in experimental *restinga* parcels reported in the DNER/IME Suppression of Vegetation Report (2001).

Várzea

This ecosystem is comparable to areas that are permanently flooded or near to saturation (shallow water table), where dense herbaceous strata vegetation predominates. The biomass estimate was supposed based upon a survey reported by Kask et al. (2002) for areas with these characteristics.

Mussununga

This ecosystem is comparable to open forest formations of low density and low individuals, with a dominant herbaceous strata. The estimate was based upon the reported literature for scrubland — steppe formations in transition in ecological tension (ecotones), reported in the RADAMBRASIL project (*apud* Bernoux et al. 2001).

Brejo

This ecosystem is comparable to a permanent swamp forest, a permanently flooded forest, which occurs on soaked soils frequently formed by dammed up water occurring behind riverbanks in areas where there is a depression. It presents few species but the trees often are large. The estimate was supposed based upon the literature reported of the phytomass of the arboreal strata, flooded or floodable, of forest-scrubland transitions located in latitudinal bands similar to those of Bahia and Espírito Santo (Rezende et al. 2001).

*Source: Estimate of biomass and carbon stock in Aracruz's native areas
January 2005*

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