The Use of Geo-Information System to Ecotourism and Conservation Planning in Guaraqueçaba Protected Area, South Brazil

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1. Abstract

The 313,400 ha reserve of Guaraqueçaba in southern Brazil is part of the largest remaining fragment of Atlantic Forest, one of the most diverse yet endangered ecosystems in the world. It was selected by UNESCO as a Biosphere Reserve. The area comprises diverse ecosystem of mangroves and Ombrophyla Dense Forest (lowlands, lower montane and montane). To support conservation and ecotourism planning there we needed recent, digital information on deforestation and vegetation cover. This paper presents the use of TM Landsat image and GPS located training plots to updated vegetation, landuse, and ecotourism sites maps. The geo-information gathered is stored in a relational geographic database which allows to quantify the present relation between accessibility and deforestation. Besides the current information assists ecosystem planning by locating examples of ecosystems that are potentially attractive to ecotourism and by zoning the vulnerable areas.

2. Introduction

The Atlantic Forest ecosystem covers a strip along the mountainous coast of southeastern Brazil and is one of the biotically most diverse ecosystems in the world, more even than its famous cousin the Amazon (PEIXOTO, 1992). The region’s wet tropical conditions make it especially rich in epiphytes, such as orchids and bromeliads, but other taxa are also abundantly represented. Typical tree species diversity is about 120-160 species per hectare (KLEIN, 1995). Many species are found nowhere else in the world: perhaps half of the tree species and two thirds of all herbaceous plants are endemic to this ecosystem (PEIXOTO, 1992; PYE, ANTUNES & MULLER, 1995).

According to the Brazilian vegetation classification system proposed by VELOSO & GOES (1982) and adopted by IBGE (Brazilian Institute of Geography and Statistics) the Ombrophylous Dense Forest (O.D.F.) was divided into Lowland Forest, Lower Montane Forest, montane Forest and Pioneer Formations of fluvial, marine and fluvizomarine influences.

The study area comprises the Superagui National Park in Guaraqueçaba Bay. This Park is composed of delta islands formed in the Holocene period. The islands' vegetation ranges from lower montane forest to mangroves. Situated in the wetlands and estuaries they form a physiographically and biologically diverse area of considerable importance in the Protected Area of Guaraqueçaba.

New human activities in the region affects the region's natural systems e.g.because of logging (CUBBAGE et al.). The first step of this study is to generate vegetation and landuse maps so as to evaluate the area's natural conditions by means of Remote Sensing techniques. The vegetation and landuse maps will be supplemented with socio-economic data to define critical and sensitive areas within the region and toprovide a baseline for monitoring ecological changes in the future.

Figure 1. Location of the Guaraqueçaba Environmental Protected Area (APA).

3. Methods

3.1 Image Classification

A cloud free *Landsat* image of Guaraqueçaba from July 1993 and some GPS land use samples were obtained from Federal University of Parana Geoprocessing Center and from SPVS (NGO) donation to this study

The image was composed of bands 2,3,4,5 and it was previously rectified (FIGURA 2) from GPS control points (PYE et al., 1994).

Supervised and non-supervised classification methods were used to select more significant training areas. The signature collection was based on clustering, vegetation index, image interpretation from fieldwork and GPS points.

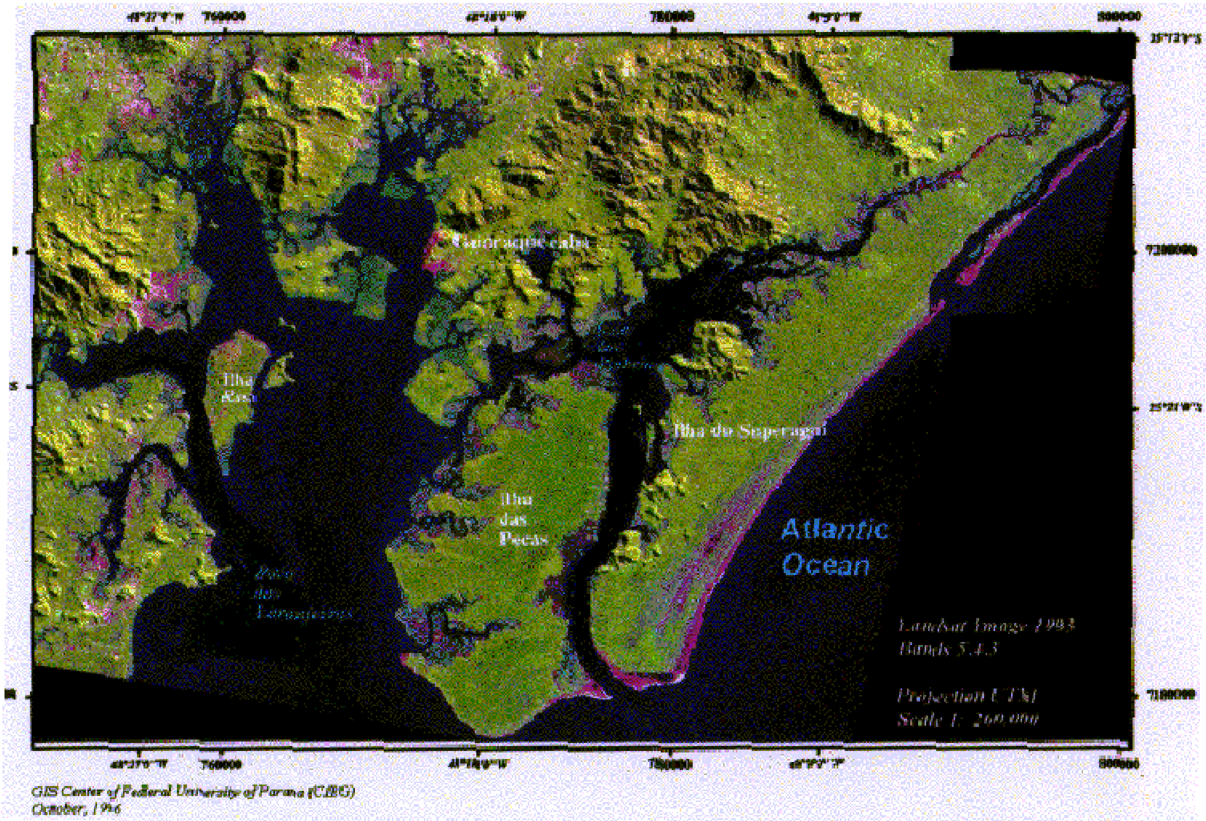

Figure 2 **Color composite (RGB), bands 5,4,3 of the study area: Guaraqueçaba (APA), Parana, Brazil.**

The maximum likelihood method was chosen for image classification, using ***Erdas Imagine 8.1***. A majority filter was used to eliminate image noise (*salt and peppers)*. The vegetation classes of the thematic image are described in Table 1. The accuracy assessment of this image was done using an error matrix. Reference points were chosen for random stratified sampling (CONGALTON, 1991).

The *Kappa coefficient* (k%) proposed by COHEN (1960) expresses the agreement between the reference points collected in the field and the categories on the map if as the condition of random agreement is removed. The *Kappa coefficient* (Table 2) is highly recommended for accuracy assessment of remotely sensed data (CONGALTON, 1991; LINGNAU & ANTUNES, 1996

Table. 1. Vegetation categories mapped (ANTUNES, 1996)

Categories	Description
O.D.F. Low Montane	Cover the terrain higher of 50 meter of altitude. Mainly composed of secondary forest.
Pioneer Formations of Fluvial Influence	Located in swamped areas with hydromorphic soils between the old dunes;
Pioneer Formations of Fluviomarine Influence(mangroves)	Mangroves communities mainly concentrated in river deltas which form estuary (Guaraqueçaba Bay);
Pioneer Formations of Marine Influence	Sand vegetation situated in dunes under the eolic influence;
O.D.F Lowlands	Alluvial forest situated in the transition zones of Low montane forest and Pioneer formations;
Altered Vegetation	Modified forest as result of anthropic activities.Early sucessional woodland.

Table 2. Accuray assessment classification and Post-classification.

CLASS	K%: Classified Image	K% : Post-classified Image
O.D.F. Lower Montane	70.12	95.41
P.F. Fluvial Influence	70.11	79.83
P.F. Fluviomarine Influence	80.25	91.38
P.F.Marine Influence	68.25	88.81
O.D.F. Low Lands	69.57	89.90
Altered Vegetation	77.43	93.67
Bare Soil	83,70	89,11
TOTAL	*74.20*	*89.69*

3.2 Digital Elevation Model

The contour lines from topographic maps (1: 50,000) of Guaraqueçaba were digitized in *ARC-INFO* (version 7.02). After the topology creation, the TIN module was used to generate a lattice surface with spot heights. This lattice surface was exported to *ERDAS Imagine* format.
In that image file, each *pixel* (spatial resolution of 30 x 30 meters) is attributed as equivalent altitude. The image attribute table stores the number of *pixels* associated with a certain altitude (ANTUNES, 1996).

3.3 Post- Classification

The classified image and DTM image were used in the classification process. All vegetation categories were corrected with their altitude. According to RODERJAN C. & KUNIYOSHI (1988) the Ombrophilous Dense Forest formations vary with altitude, as follows:

0- 50 meters: Lowlands
50- 600 meters: Lower Montane
600- 700 meters: Montane

Using the *Spatial Modeller* module of *Erdas Imagine,* a routine was created to reclassify the image.

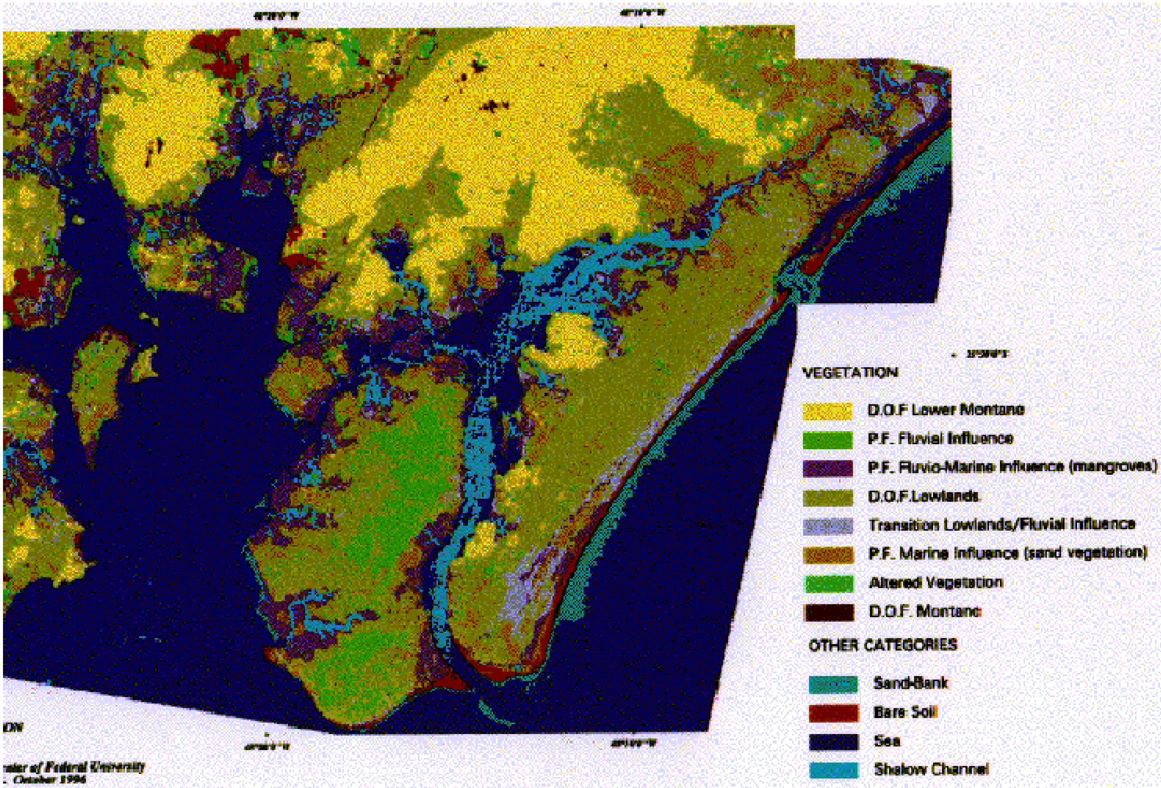

Figure 3 Reclassified Image of the Superagui Island.

As a result of this procedure, categories such as Lowlands and Lower Montane, which had very similar spectral response, could be better distinguished. Shadows could thus be completely eliminated and reclassified according to the altitudes (Figure 3).

1- Sand Vegetation(P.F. Marine Influence)
2- P.F. Marine Influence(advanced sucessional fase)
3- P.F. Fluvial Influence
4- O.D.F. Lowlands
5- O.D.F. Lower Montane
6- P.F. Fluviomarine Influence (mangroves)

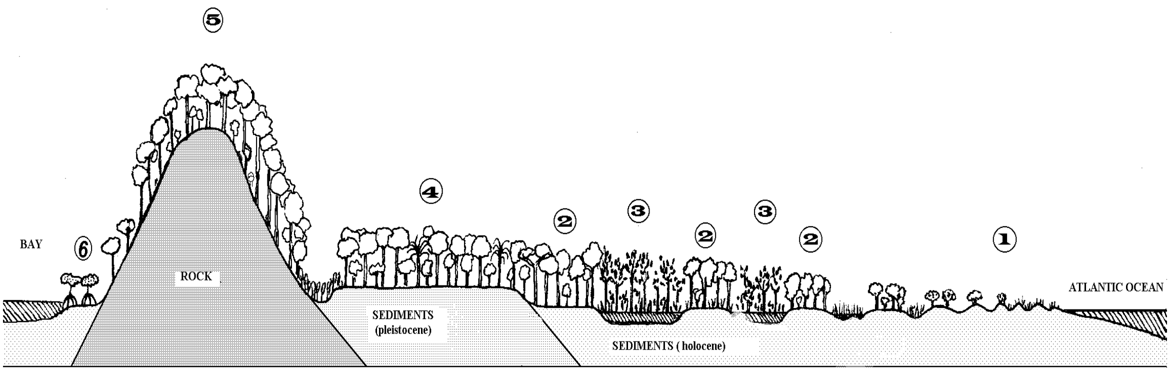

Figure 4. Vegetation profile of a 4.7 Km long, *East-West* transect of Superagui Island (JASTER 1995).

The accuracy assessment yielded a superior Kappa-index compared to the classified image (Table 2). The overall accuracy improved by about 15.5 %.

JASTER (1995) made a vegetation profile of *Superagui Island*. This profile (Figure 4) agrees for 88 % with the vegetation map (Figure 3). Field checks (ground truth) confirmed the accuracy of the classified data. The main divergence between the profile and the vegetation map was attributed to *Fluvial influence* which was classified in the image as *mangroves* (fluviomarine). These categories have similar spectral characteristics as percieved by the signatures editor (ANTUNES, 1996).

The classified image is associated with anattribute table, which stores area and number of pixels for each category. The attribute table allows evaluating land and forest covers and might be useful in GIS-analysis (TABLE 3).

Table 3 Quantity of forestland and non-vegetation land categories in classified image, (ANTUNES, 1996).

Vegetation	Area(Ha)	Percentage %
O.D.F. Lower Montane	20.758	24.95
O.D.F. Lowland	29.783	35.83
O.D.F. Montane	260	0.32
P.F. Marine Influence(sand vegetation)	10.660	12.82
P.F. Fluvio-Marine Influence (mangroves)	10.710	12.88
P.F. Fluvial Influence	5.562	6.69
Altered Vegetation	2.906	3.50
Bare Soil	2.494	3.00
TOTAL	83.133	100

4. Conclusion

The combination of Digital Elevation Model (DTM) and conventional procedures of image classification may reach good results in mapping the Dense Ombrophilous Forest segmentation.

The accuracy assessment plays an import part in the remote sensing technique in providing a reliable spatial analysis.

The reclassification process with DTM generated from topographic maps contour lines grants better results, eliminating some misclassification errors.

Multitemporal analysis could be achieved comparing imagery from different times associated with DTM, allowing the monitoring of deforestation and environmental degradation (TABLE 3). The image processing might prove to be an advantageous (inexpensive) tool in aiding the local authorities control undesirable changes in Environmental Protected Area, such as Guaraqueçaba.

Besides these data will be linked to geographic database which allows the definition of critical and sensitive areas in the region and the choosing the more suitable areas for ecotourism.

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