Remote Sensing and GIS Techniques Applied to Highway Planning: Case Study Ring Road Project (RODOANEL) Surrounding São Paulo Metropolitan Region, Brazil.

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ABSTRACT

This study presents a remote sensing and GIS application to analyze the ground appropriateness to locate and construct the *Rodoanel* highway, a ring road surrounding the São Paulo Metropolitan Region (SPMR). This study was made in close cooperation with the São Paulo State Department of Roads (DERSA). It corresponds to section 1 of *Rodoanel*, whose construction will start in 1998. This Road Department provided documents with several alternative locations for the *Rodoanel*, which is presently the most important highway construction project in Brazil. To evaluate the aptness of this area for huge civil engineering works, we made a map of land cover units using TM-Landsat (bands 1,4,7), which was associated to maps of slopes and geomorphology in a GIS environment.

INTRODUCTION

The objective of this study is to setup a methodology for the analysis of the feasibility of directives for road construction established by DERSA, using remote sensing and GIS techniques. The *Rodoanel* project is at the reconnaissance phase, which is the ideal moment for surveys with TM-Landsat images, followed by a detailed but costly aerophotogrammetric survey, as suggested by (2).

The first section to be build of this highway will cross an area of high population density, characterized by an intense conurbation process, including 11 municipalities.

METHODOLOGY

A map of land cover was made (Fig. 1.a), thematic maps were digitized and inserted into a GIS, in order to obtain parameters to analyze the feasibility of alternative locations for the highway. The data analysis and processing software used was SPRING, developed at INPE. Phases of this study:

1). Mapping of Land Cover: initially a land cover map was made (Figure 1.a), using TM-Landsat bands 1, 4 and 7 (path/row 219/76, quadrant C, acquisition date: Feb.9 '97), which is very useful for the analysis of urban classes according to (3). Ancillary data: aerial photographs (scale: 1:25,000) and 35mm photographs from field survey. This map presents 8 classes of urban use, 4 classes of vegetation and a class of water bodies (rivers and lakes). It was obtained following 3 working steps:

- To each TM band a linear contrast stretch was applied, to better discriminate among the land cover types associated to digital numbers.
- This dataset was then segmented using region growth, according to 8 gray levels of similarity and 10 pixels of minimum area.
- The segmented areas were then labeled for supervised classification, based on 59 training areas, using Bhattacharrya distance and an acceptance threshold of 95%.

2). Setting up a Data Bank: thematic maps of geomorphology (Fig. 1.b) and topography (Fig. 1.c) were digitized.

3). Manipulation of Information Plans: on the thematic maps we performed pixel-by-pixel operations and the result was a map of qualitative terrain aptness for road construction, indicating conditions "good", "fair" and "poor" (Fig. 1.d).

The adequacy to different physiographic units was described at a scale of weights, varying from 0 to 9, using a weighting operation, where digital data of a thematic class are converted to a numerical class (Table 1).

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A new regular grid of weights was created to receive the entire grids of geomorphology, slope and land use.

The final grid was sliced according to Table 2, and the thematic map of physical aptness was obtained.

Table 1 - Weights attributed to classes of Information Plans.

Information Plan	Class	Weight
Slope	Below 5 %	0
	5 a 20 %	3
	20 a 40 %	6
	Above 40 %	9
Geomorphology	Floodplain	0
	Low hills	3
	High hills	6
	Mountain	9
Land use	Not occupied area	0
	Low density occupation	6
	High density occupation, Industry	9
	Forest, Water bodies	9

Table 2 - Physical aptness of terrain classes and intervals

Terrain aptness class	Weight interval
Good	0 - 7
Fair	8 - 17
Poor	18 – 27

Table 3 - Rejection index for a possible road location

Class	Extension (m)	Difficulty grade	Difficulty level
Good	15330	0	-
Fair	750	1	750
Poor	10740	2	21480
Total	**26.820**	-	**22230**
		Rejection index	**0.83**

RESULTS AND DISCUSSION

The procedure presented here is adequate for highway projects in complex occupied areas, also allowing the inclusion of data referring to environmental and social impacts that can be mapped. This enables a multi-thematic analysis required by the *reconnaissance phase* of such a project.

TM-Landsat images discriminated among large industries, areas with high occupation density and forest, which are those classes of most interest for highway planning. Apparently the parameters that most influenced the classification of these areas were: size, vegetation index and spectral signature.

Through the map of physical aptness, parameters for evaluation and comparison were obtained, that are very useful when applied to the highway location alternatives, at this section of the *Rodoanel.*

At the visual evaluation, the class "fair" must be considered as "good" or "poor", after checking the corresponding relief, the slopes and land use of the alternative that is being considered.

CONCLUSIONS

The methodology presented here helps to define the highway location, but it does not exempt the project of a photogrammetric survey, absolutely necessary here, for the precise location. Maps of physical aptness optimize the location of roads, by the visual identification of adequate areas for this huge engineering effort and to make comparisons among alternative locations, and to describe the aptness of the terrain to be crossed by these alternatives.

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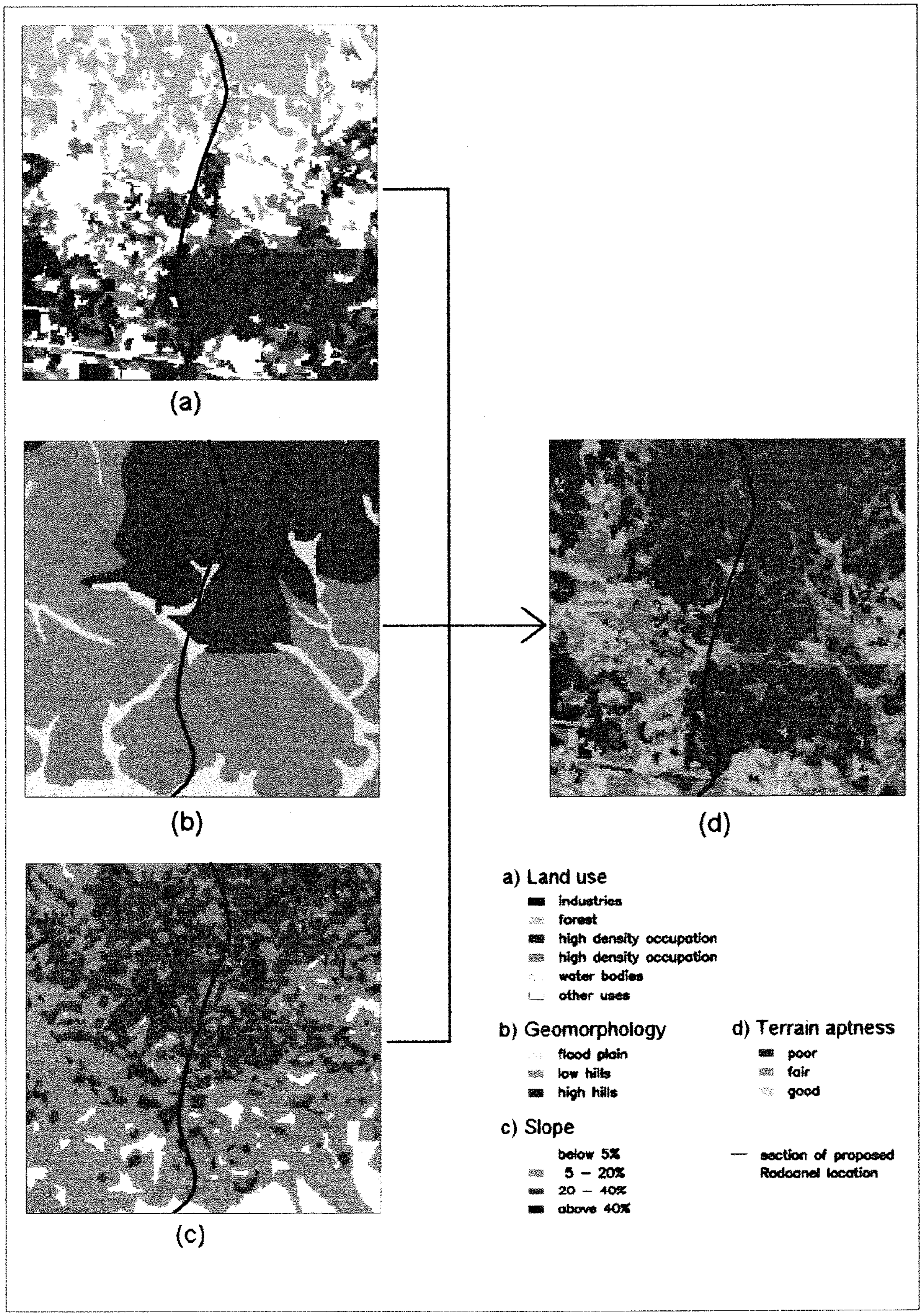

Fig. 1 - Terrain aptness (d) obtained from maps of land use (a), geomorphology (b) and slope (c).