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## TEMPORAL ANALYSIS OF URBAN EXPANSION IN EROSION RISK AREAS USING REMOTE SENSING AND GEOPROCESSING TECHNIQUES

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### ABSTRACT

Most Brazilian cities grow-up chaotically. The urban occupation frequently occurs without considering the physical environment, interfering negatively with the population quality of life, causing many negative consequences at short, medium and long range. The municipality of São José dos Campos had an accelerated growth during the last two decades, especially in the Eastern and Southern regions, where urban occupation occurred at inadequate places. The result of such an unordered occupation is an environmental disturbance, high costs for the Government, and risks for the population. This study presents a methodological approach for the use of aerial photography at scales 1:25,000 and 1:8,000 that were obtained in 1985 and 1997. These data were analyzed and interpreted according to remote sensing procedures, and the result is a map of the urban growth areas in the Eastern sector of São José dos Campos for the two dates under study. In order to evaluate the urban growth on erosion risk areas, a potential erosion risk chart was used for the area under study. Using geoprocessing techniques, comparisons were made between the erosion potential chart and the human occupation for the period under study, and several risk classes for this area were established. So it was possible to quantify the urban growth rate for the period, as well as expansion over erosion risk areas.

### 1 INTRODUCTION

The industrial development in the region “Vale do Rio Paraíba do Sul” in São Paulo State, started during the fourth decade of the XX Century, in parallel with the urban expansion, which became the dominant characteristic of the spatial organization. This characteristic can be seen both in the increase of urban population as well as at the territory occupied by these activities. Being so, it is necessary to know the features and effects of urbanization to understand the significance of this phenomenon but also to gather information for urban and regional planning.

It is possible to deduce that the chaotic and irregular urban occupation can cause many problems, such as those related to environment and to the non-discriminated occupation of the floodplain, which are areas subject to inundation, and those sections with steep slopes, that are areas of high susceptibility to erosion processes, as it was shown on studies by Escada (1992), Vieira & Kurkdjian (1993), Costa (1996), Serafim (1998), among others.

It is important the planning for the growth of cities and to study the growth tendencies in its relation to the physical environment. In this frame, conventional techniques, i.e. the analysis and interpretation of aerial photography has demonstrated its' applicability to map urban areas, as seen in Mumbower & Donoghue (1967), Santos et al. (1981), Welch (1982), Kurkdjian (1989).

The use of remote sensing techniques together with Geographic Information Systems (GIS), becomes more and more fundamental instruments for the analysis of urban phenomena and to obtain relevant information for the physical planning of the territory, as shown in works by Foresti (1990), Escada (1992), Kurkdjian et al. (1992), Vieira & Kurkdjian (1993), Costa (1996), Valerio Filho (1998) and Serafim (1998). So, the objective of this paper is to monitor the dynamics of urban growth in areas of risks for the occupation, using remote sensing and geoprocessing techniques.

## 2 MATERIALS AND METHODS

### 2.1 Municipality of São José dos Campos

The municipality of São José dos Campos is located at the Eastern portion of São Paulo State, Brazil, in the region called "Vale do rio Paraíba", limited by geographical coordinates S 23°20'00" WGr 45°52' 30" and S22°47'30", WGr 45°41'15" (Figure 1). It has a total area of 1,118 km<sup>2</sup>, and a population of approximately 442.000 inhabitants (IPT, 1996).

It is presently the most important and influential municipality in the region, according to official statistics (Secretaria do Meio Ambiente – SMA, 1989). The most prominent sector is the industry for of durable consumption and capital goods, favored specially by its' location between the two largest urban and industrial centers of the country (São Paulo e Rio de Janeiro) (IPT,1996).

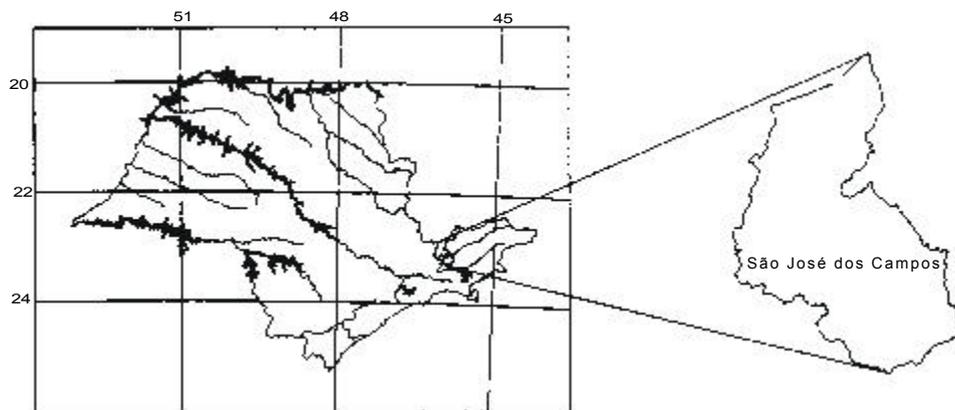


Figure 1 - Localization of municipality São José dos Campos within São Paulo State.  
Source: IPT, 1996.

The consequence of the consolidation of São José dos Campos as an industrial center was the exodus from rural areas, the expansion of the urban area and the frequently inadequate occupation of problematic areas, besides the deficiency of the urban infrastructure needed (IPT, 1996).

### 2.2 - Area under study

In order to develop this study, the basin of Pararangaba creek was selected, including also a section from the basin of the Rio Paraíba do Sul (Figure 2), totaling an area of 73,20 km<sup>2</sup>, inserted in the Eastern sector of the municipality São José dos Campos, because this is an area with intense human occupation, after the last two decades, according to Serafim (1998).

The following ancillary data were used: topographic maps from Instituto Geográfico e Cartográfico (IGC) at 1:10,000 scale, planimetric/altimetric maps from Instituto Brasileiro de Geografia e Estatística (IBGE), at 1:50,000 scale; Geotechnical Map of Municipality São José dos Campos, at 1:50,000 (IPT, 1996), GPS Garmin Survey II for georeferencing of information obtained during field survey; aerial photos at approximate scale 1:25,000 (1985) and color aerial photographs at approximate scale 1:10,000 (1997).

The equipment used were: light table and mirror stereoscope for the interpretation of aerial photographs, workstation with SGI/INPE GIS package; color printer and software to process data, developed by the Laboratory for Geoprocessing from UNIVAP – University Vale do Paraíba.

Mapping of urban areas was performed using criteria for analysis and interpretation applied to black and white and color aerial photographs and field survey, according to procedures suggested by the American Society for Photogrammetry (1960), Marchetti & Garcia (1986), Pereira et al. (1987), and Novo (1989). The analysis of urban growth in the erosion risk areas for the period analyzed was made through geoprocessing techniques, by

superposition of both maps of urban areas (1985 –1997) with the available map of potential erosion risk (Serafim, 1998).

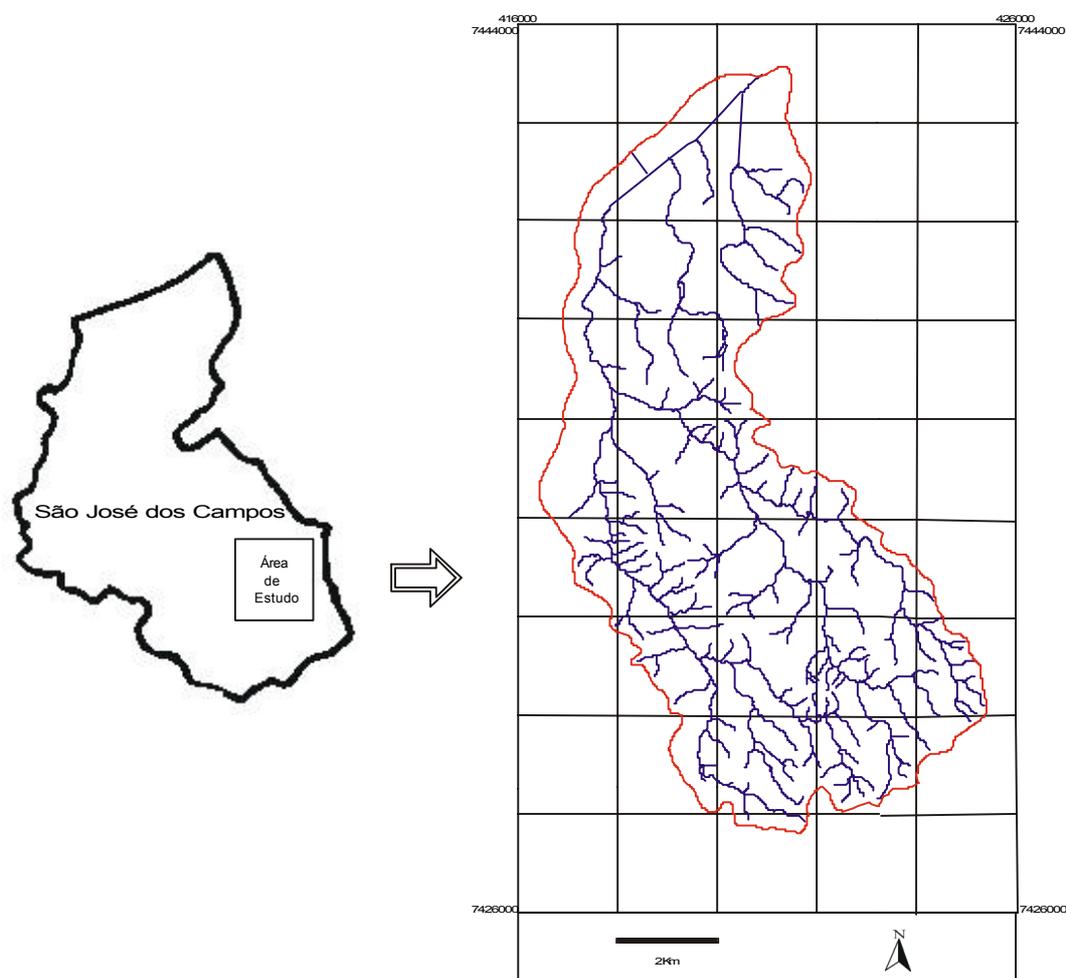


Figure 2 - Localization of area under study (Pararangaba creek basin).

### 3 RESULTS

The analysis and interpretation of both data sets, i.e. black and white and color aerial photographs, allowed the elaboration of a map from urban areas for this timeframe. Figure 3 presents the spatial distribution of the urbanized area for both dates, and Table 1 shows the results of urban growth for the period analyzed.

According to Table 1, one can verify that in the timeframe 1985-1997 there was a significant increment of urbanized area, that can be seen at Figure 3. The increase of urbanized area was also confirmed by Serafim (1998), while he was performing a mapping of urban growth, supported by TM-Landsat images.

Referring to the urban growth, according to Table 1, it is necessary to inform that part of this increment is related to the peculiarities of those areas mapped as “urbanized”. In this region there are several new allotments, i.e., areas in the urban perimeter which are in the phase of consolidation, and as such they don’t present the typical photographic patterns for consolidated urban areas. Being so, part of those spaces contained within the urbanized perimeter are computed as “urbanized area” even considering that they are not entirely consolidated.

Basin of Pararangaba creek	Area (Km <sup>2</sup> )	Area (%)
Urbanized area in 1985	2.80	3.82
Urbanized area in 1997	8.06	11.01

Table 1 – Quantification of urbanized areas within the sector under study.

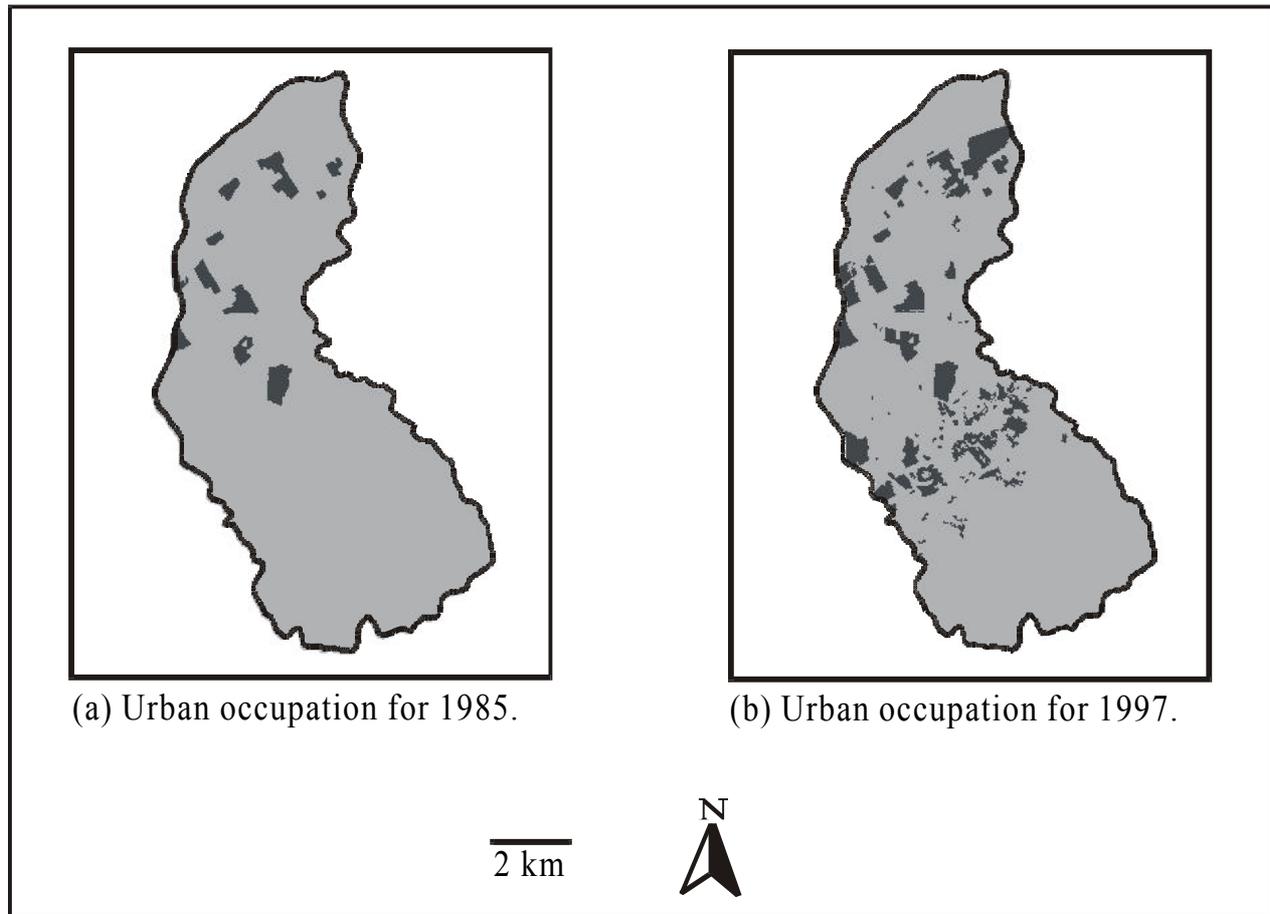


Figure 3- Map of urban occupation of the Pararangaba creek, for 1985 (a) and 1997 (b).

Furthermore, it is necessary to inform that in the area under study, many new allotments are illegal, while other allotments were implanted initially as larger properties for leisure, which afterwards were divided into smaller lots, but without the basic infrastructure approved by the Government. It is worth to mention that in this area there are still allotments of properties for leisure, located to the South of the basin, in the contact with the rural area. Due to these conditions, it is quite difficult to discriminate on the thematic map, the precise location of limits from the urbanized areas, because of the great diversity of occupation and photographic patterns, analyzed on both B/W and color aerial photography used.

Due to these limitations, it is to say that the quantification of the urbanized areas made in this study should be analyzed taking into account the restrictions related to its' identification, as mentioned.

The thematic maps for the urbanized areas during 1985 and 1997 were digitized using geoprocessing techniques to allow the temporal analysis of urban growth in erosion risk areas.

The analysis of urban growth in erosion risk areas for the period analyzed, was performed by the superposition of maps of the urbanized perimeters of both dates with the erosion risk map, which was obtained through the integration – using geoprocessing techniques – of parameters related to geotechnical units, soil units and slope inclination classes, according to Serafim (1998) which, in this study was adapted to a smaller number of classes of potential soil erosion.

The spatial results of merging maps from urbanized areas with potential erosion risk maps, can be seen on Figures 4 (1985) and 5 (1997). Table 2 presents quantitative data of urbanized areas in the respective classes of potential erosion risks.

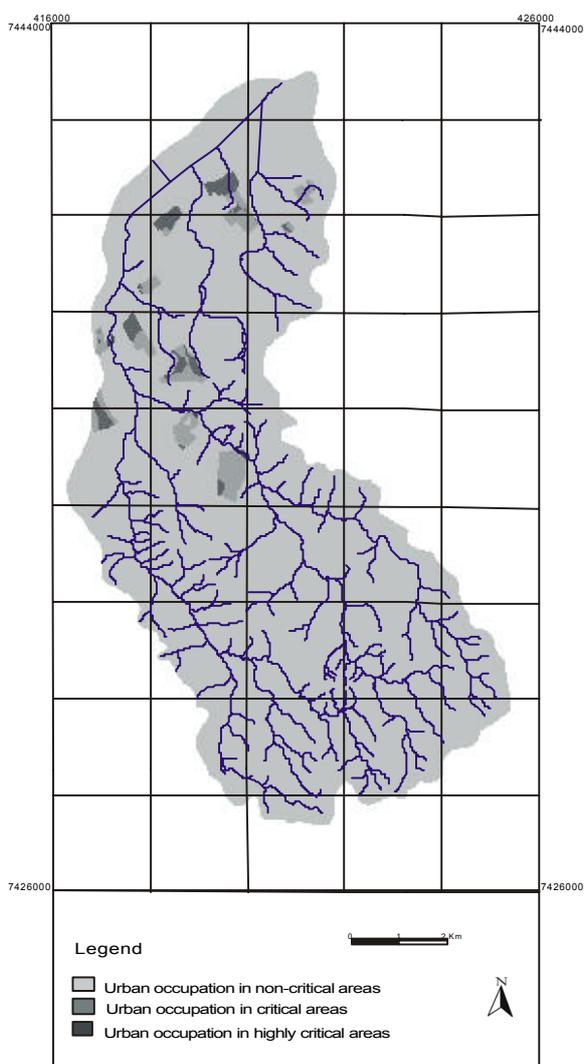


Figure 4 - Urban occupation in areas of potential erosion risks for the year 1985.

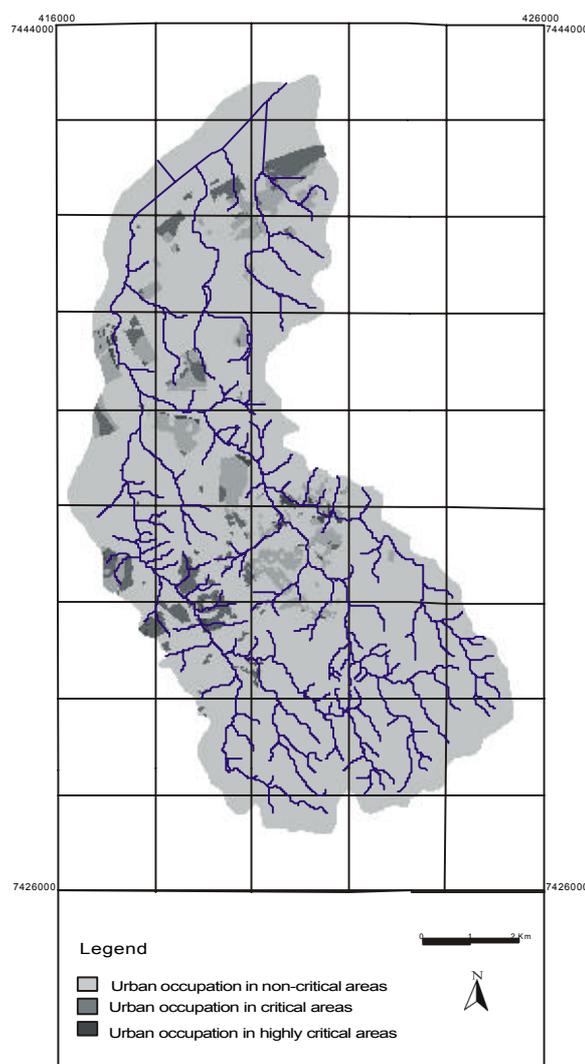


Figure 5 - Urban occupation in areas of potential erosion risks for the year 1997.

According to Table 2 and by comparative analysis, one can verify that during the period analyzed, there has been a decrease of urbanization in areas considered as favorable, which is partially responsible for the increase of urban growth in critical and very critical areas, perceived also at Figures 4 and 5. At these figures one can observe that part of the urbanized areas within those classes of potential erosion risks considered as critical and very critical are found mainly close to the drainage or to water heads with erosion, which are high risk areas, respectively for inundation and erosion processes, according to what was observed during field survey, performed to verify the occupation and photographic patterns, defined in the aerial photographs.

One could verify, according to Table 2, that during the period analyzed, there was an increment of approximately 9,5% of urban growth in areas considered as of potential erosion risks (0.76 km<sup>2</sup>) according to what is demonstrated also

by Figures 4 and 5. Taking into account that this area of study is located at one of the most favorable regions for urban expansion which, according to Serafim (1998), presented a high urbanization rate in the last few years, it is mandatory that the Municipality of São José dos Campos acts in order to control the advance of this chaotic urban growth, in order to avoid the environmental impacts as well as the negative consequences to the society as a whole.

Classes of potential erosion risks	Urbanized area 1985 (km <sup>2</sup> )	Urbanized area 1985 (%)	Urbanized area 1997 (km <sup>2</sup> )	Urbanized area 1997 (%)
Non-critical areas	1,84	65,24	4,61	57,20
Critical areas	0,90	31,93	2,87	35,61
Highly critical areas	0,08	2,83	0,58	7,19

Table 2 – Quantitative data of urban growth at classes of potential erosion risk, as related to the total urbanized area for each date (1985 e 1997).

#### 4 FINAL CONSIDERATIONS

The methodology used in this study, even considering some limitations of higher efficiency for mapping urbanized areas, demonstrated that, using remote sensing techniques applied to the analysis and interpretation of B/W and color aerial photography, it was possible to identify those areas of urban growth for the period 1985-1997, which were made using geoprocessing techniques, merging the respective surveys with the potential erosion risk map, which allowed a quantitative temporal analysis of urban growth in erosion risk areas of the Pararangaba creek basin, within São José dos Campos municipality.

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