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GROWTH OF SÃO PAULO METROPOLITAN AREA

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14. Abstract/Notes

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Mapping the urban growth over the period from 1977 to 1979 and identifying
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THE USE OF LANDSAT DATA TO MONITOR THE URBAN GROWTH OF
SÃO PAULO METROPOLITAN AREA*

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ABSTRACT

The urban growth monitoring of São Paulo Metropolitan region has been done by conventional techniques which involve a high cost sistematic control. On the other hand, the orbital remote sensing allows a continuous land use control at lower cost.

For being under governmental control the region located between Billings and Guarapiranga reservoirs was chosen as test site for monitoring urban growth through LANDSAT data.

Mapping the urban growth over the period from 1977 to 1979 and identifying the problematic urban areas with several LANDSAT products constitute the basic aims of this work.

Visual and automatic interpretation techniques were applied to the data. Computer compatible tapes (CCT) of LANDSAT multispectral scanner data were analyzed through the Maximum Likelihood Gaussian algorithm. The results pointed out the feasible monitoring of fast urban growth by remote sensing techniques leading to an efficient urban planning and control.

1.  INTRODUCTION

The urban growth monitoring of São Paulo Metropolitan region has been done by conventional techniques which involve a high cost due to the need of a sistematic control. On the other hand the orbital remote sensing leads to a continuous land use control at lower cost.

By selecting as test area the south region of São Paulo Metropolitan area located between the Billings and Guarapiranga reservoirs (Figure 1), one aimed at some specific goals in this study stated as follows:
- to analyse the performance of several LANDSAT products (MSS, RBV and CCT) for monitoring urban growth;
- to derive the spectral response in the rural-urban fringe;
- to map and evaluate the urban growth over the period from 1977 to 1979;
- to identify the problematic areas where a very careful governmental control becomes necessary.

The choice of the study region was based upon several reasons like:
- it presents high rates of urban growth;
- it is already under a governmental control by a specific law called "fountainhead protection act";
- it is bounded by water bodies which are useful as control points for comparison of data obtained from different dates.

## 2. MATERIAL AND METHOD

### 2.1 TEST AREA

The test area corresponds to the south of São Paulo Metropolitan area. It is located between the Billings and Guarapiranga reservoirs and extends from the junction of Grande and Guarapiranga rivers to the parallel 23°49'S.

According to Emplasa (1980) the fastest growth of São Paulo Metropolitan area, from 1974 to 1977 was verified in the south area. This area presented 21,65 km$^2$ of expansion during this period which represented about 45% of the growth in the Metropolitan area. The high rates of urban increase are due to the development of a very attractive industrial concentration. Another reason for this·fast growth comes from the influences of its neighbourhood which is also industrialized. In addition, this area does not present any restriction to the urbanization concerning to its physical characteristics.

### 2.2 MATERIAL

The work was developed using LANDSAT products (row path annotation 164/28) as described in Table I.

Computer compatible tapes were analyzed using Image 100 described on General Electric (1975).

In addition, land use of Great São Paulo at the scale of 1:50.000 (1977) and photo indice (1980) at scale 1:32.000 were also available to assist the analysis of·the data.

### 2.3 METHOD

The development of the work implied the following steps:

### 2.3.1 VISUAL INTERPRETATION

In the visual interpretation of MSS imagery the urban area was separated from the surrondings using conventional criteria of photointerpretation such as grey level, texture and site aspects. The land use map available and the photo indice from 1980 were used to help the delimitation of rural-urban fringe.

The superposition of the overlays obtained from visual interpretation for different periods permitted a better definition of urbanized area.

With the help of ground observation urban areas that presented difficult spectral separability were identified.

After including the built up area, growing urban area and urban allotment as urban area, it was calculated the total surface of these areas for the different periods of analysis.

### 2.3.2 AUTOMATIC INTERPRETATION

The automatic interpretation of LANDSAT data was carried out using a Maximum Likelihood algorithm (Velasco et alii, 1978). With the aid of land use map of São Paulo Metropolitan area, training areas were selected, on the display of the Image 100, for the following classes: built up area, urban allotment, dense vegetation, scattered vegetation and water bodies with

different amount of sediments. The samples of each class were selected carefully so that they could be considered representative of the respective land use classes.

The computer program "Cálculo de área" available at the library of the Image-100/INPE was applied to calculate the area of each urban class.

### 2.3.3 URBAN GROWTH: A COMPARATIVE ANALYSIS

On the urban growth analysis, it was only considered the data obtained from visual interpretation of MSS imageries.

The automatic analysis data were not taken into consideration since some difficulties occurred in selecting representative samples of urban areas for 1977.

From the overlays superposition obtained by visual interpretation, it was possible to identify the areas where a very careful governmental control is required. The analysis of superposed data allowed the localization of the largest urban growth areas.

### 3. RESULTS

### 3.1 VISUAL INTERPRETATION

With the MSS band 5, it was possible to identify the following classes: built up area, growing urban area and urban allotment. It was considered as growing urban area the partial or completely edified regions not agglutinated to the continuous urban nucleus.

The visual interpretation comparison with previous data pointed out that several horticulture regions were, in the past, uncorrectly classified as urban areas. According to Wehrwein (1959) the rural-urban fringe can be defined as the area of transition between well recognized urban land uses and the area devoted to agriculture. In many cases the economic and sociological city (the area within which people live the urban way of life) has extended far beyond the city limits; in other cases farms on wich people live the rural way of life are found within the political boundaries of cities.

Due to these aspects, the rural-urban fringe constitutes a very difficult region to be delimitate.

To make easier the separability between urban area and horticulture regions, it was tried the spectral analysis of the MSS band 7.

By analysing the data obtained from MSS bands 5 and 7, one can be resumed the following results:

- the continuous urban areas presented large tonal and texture variations in both bands. The reason for that may be related to the co-existance of arbored and high demographic neighbourhoods as observed in the field check;
- the urban growth and horticulture areas appeared with similar tonalities in both channels. They showed light grey levels in channel 5 while large tonal variations were observed in channel 7;
- some horticulture area were showed with light grey levels in channels 5 and 7 similar to the allotment areas response;
- since the horticulture area did not appear with a regular shape in channel 5, it was very difficult to separate it from the urban areas. The main reason for this irregular behaviour of the analyzed horticulture regions comes from their small sizes;
- the localization itself was not so important in the identification of the urban and horticulture areas since both land uses are contiguous.

3.

Therefore it was not possible to discriminate urban from horticulture areas only by conventional visual interpretation of LANDSAT imageries. So, a temporal analysis was performed through a map comparison from different dates. From the overlays superposition one could make the following conclusions:

- the correctly mapped urban areas showed an increase in area, during the period of 1977 to 1978, without any significant tonality modification, while the horticulture zones mapped as urban, displaied different tonalities and localizations. As a consequence, several light grey levels areas considered as urbans in 1977 did not present the same tonality in 1978;
- from 1978 to 1979, the horticulture areas appeared with different tonalities. However, the actual urban areas showed light grey levels for any analyzed period.

The grey level changes which occurred in the horticulture areas are due to active soil utilization. As implied by Filgueira (1972), the vegetable crop cycle is in general shorter than other cultivations, so the soil is constantly occupied.

The visual interpretation results from the MSS imagery for 1977, 1978 and 1979, are shown in the Figures 2, 3 and 4.

3.2 VISUAL INTERPRETATION OF RBV IMAGERY

The RBV imageries have spectral sensitivity from 0.505 to 0.750 µm and a spatial resolution of about 40 m. The use of RBV imagery did not improve the separation between urban areas and their neighbourhood when compared to MSS imagery (bands 5 and 7).

By the visual interpretation of the RBV imagery one could identify the following classes: built up area, growing urban area and allotment. The spectral signature of the urban area did coincide with that obtained from band 5 of MSS imageries. As occurred for the MSS band 5, some horticulture areas were also uncorrectly classified as urban.

The enlargement to the scale of 1:125.000 and the period of analyzed RBV imagery possibly made more difficult the precise urban class delimitation.

3.3 AUTOMATIC INTERPRETATION

The automatic classification of the data was performed using the Maximum Likelihood algorithm (MAXVER).

By the analysis of the sample matrices it was noted the superposition among the built up area and the allotment for every date analyzed. These classes showed higher spectral responses for the bands 4 and 5 when compared to the other classes.

The built up area presented medium values of grey levels while the allotment areas showed higher levels in channels 6 and 7. Class superposition occurred, therefore, in the visible wavelenght region. The reason for that comes from the fact that some allotment regions were already becoming urban areas.

However, the hard separability between built up area and allotment did not disturb the classification since the embankment and the scattered built up regions were considered as urban areas.

By comparing the results with existing maps it was found that the arbored urban areas were not classified as urbans. In the ground observation, it

could be noted that these regions typically present large arbored areas around sparsed residences.

Since some allotment areas were already occupied by scattered vegetation, these classes appeared overlapped in many cases.

Table II shows the obtained surface occupied by every analyzed class using the automatic interpretation.

For 1977, the allotment class was overestimated when compared to the following years as shown in Table II. This comes from the overlapping between the allotment class, the built up areas, scattered vegetation and horticulture areas for 1977.

The data for 1977 corresponde to a dry season period where a very weak spectral differentiation occurs between scattered vegetation and either bare soil or partially built up areas. At this time of the year the biomass is relatively small and so the vegetation spectral response will be modified by the reduced amount of chlorophyll. The class scattered vegetation from 1977 was classified as allotment in 1978.

By comparing the results with the available data, one can conclude that the classification obtained for 1978 is more accurate. (Figure 5).

This can be explained by the rainy period of the imagery which is followed by a strong contrast between vegetation and urban area.

The recreation areas and parks in the building urban area were classified as scattered vegetation. So the built up area was underestimated.

In the 1979 classification, the urban area increased of 12,41 km$^2$ when compared to 1978 (Table II). For that period regions close to Guarapiranga reservoir were uncorrectly classified as urbans. In the dry period, as the one analyzed, there is a lowering of the reservoir levels leading to an uncorrect classification of the borders.

3.4 URBAN GROWTH: A COMPARATIVE ANALYSIS

Based upon the urban area data obtained for the different periods, an urban growth analysis was performed in the study region.

By analyzing the Figure 6 one can observe that the urban area presented an almost constant growth in the studied periodes. Table III shows the relative growth of the analyzed urban area which indicates the major expansion rate in the period from 1977 to 1978.

One can also observe the urban growth rate became lower within the last period of analysis. In spite of this declining rate some problems occurred. The first of them is due to the fact that this region is situate at the reservoirs protection areas which are under governmental control. Another problem comes from the random urban growth leading to a chaotic neighbourhoods.

By comparing the Figures 2, 3 and 4 one verifies that the major change occurred close to the Parelheiros road and the Billings reservoir.

According to Emplasa (1980), Parelheiros showed the highest growing rate at the São Paulo Metropolitan Region with 16,28% per year from 1970 to 1979 justified by the industrial poles attraction.

The region close to the Billings reservoir and The Parelheiros road is occupied by the low income class residences with high built up density and

random growth as noticed in the ground observation.

## 4. CONCLUSIONS

The basic results of this work can be summarized in the following conclusions:

- in the urban growth study it is convenient to collect information on land use at the rural-urban fringe during the imagery selection procedure. This way, the data analysis becomes easier and more precise;
- the multidate approach allowed the discrimination between urban and horticulture areas;
- in the automatic analysis, the omission and commission errors occurred more frequently in the arbored urban and allotment areas respectively;
- the urban area analyzed growed at a rate of .28,7% during the period from 1977 to 1979. This demonstrates the needs of a sistematic land use control for this area by the governmental agencies.

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Table I. LANDSAT products (MSS, RBV and CCT) utilized
on the work

| Product | Date | Scale |
|---------|------|-------|
| MSS image | 02/24/77<br>04/05/78<br>07/04/79 | 1:250.000<br>1:250.000<br>1:250.000 |
| RBV image | 08/04/79 | 1:125.000 |
| CCT | 09/10/77<br>04/05/78<br>07/08/79 | |

Table II. Total area (km²) of analyzed class obtained by automatic
interpretation for 1977, 1978 and 1979

| Class | Area (km²) | | |
|-------|------|------|------|
| | 1977 | 1978 | 1979 |
| Built up area | 29.01 | 32.83 | 45.24 |
| Urban allotment | 40.11 | 3.74 | 3.09 |
| Dense vegetation | 26.62 | 29.23 | 39.31 |
| Scattered vegetation | 37.52 | 64.43 | 52.49 |
| Guarapiranga reservoir | 19.02 | 21.64 | 15.27 |
| Billings reservoir | 24.44 | 26.27 | 22.83 |

Table III. Analysis of the urban growth for 1977, 1978 and 1979

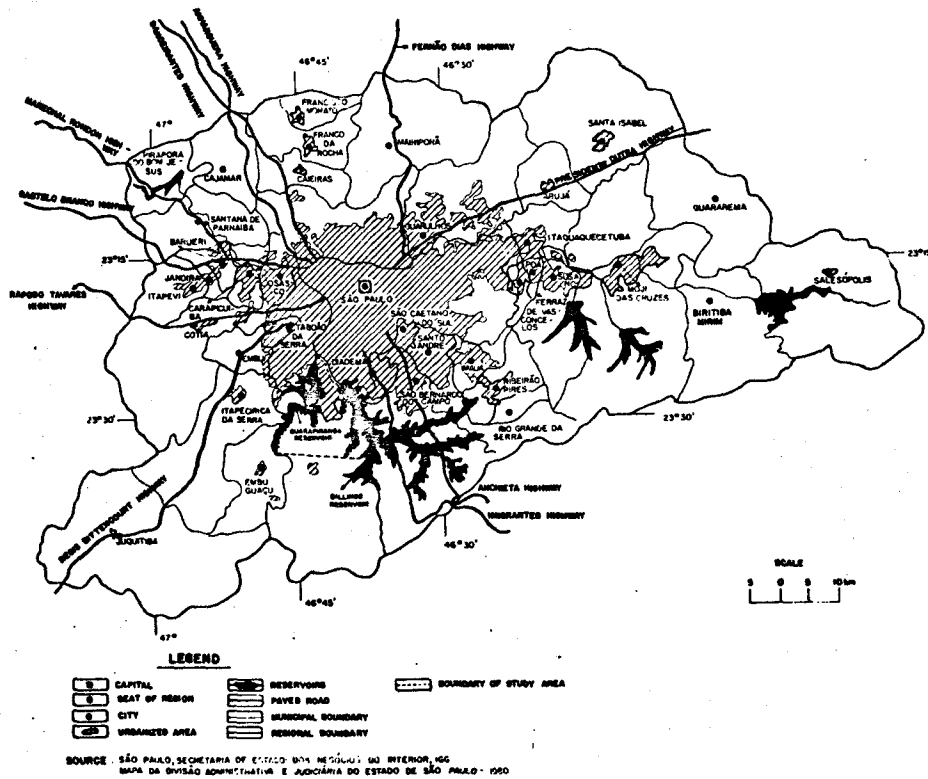| Period | Total of Urban Area (km²) | Urban growth (km²) | Growth rate (%) |
|--------|---------------------------|--------------------|-----------------|
| 1977 | 30.68 | - | - |
| 1978 | 35.50 | 4.82 | 15.70 |
| 1979 | 39.50 | 4.00 | 11.20 |

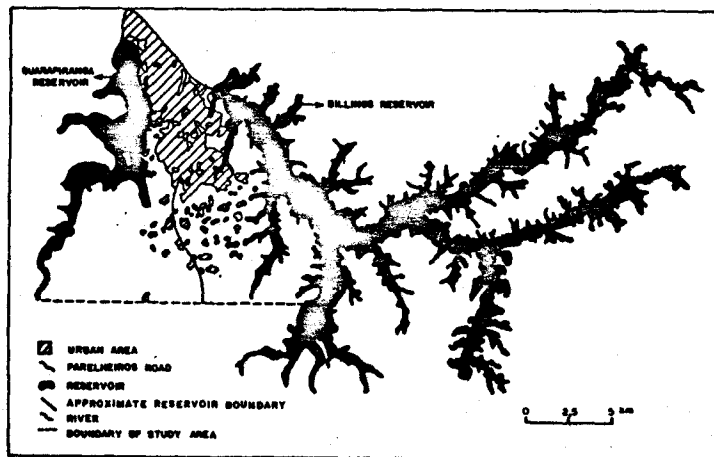Figure 1.  Localization of the Study Area.



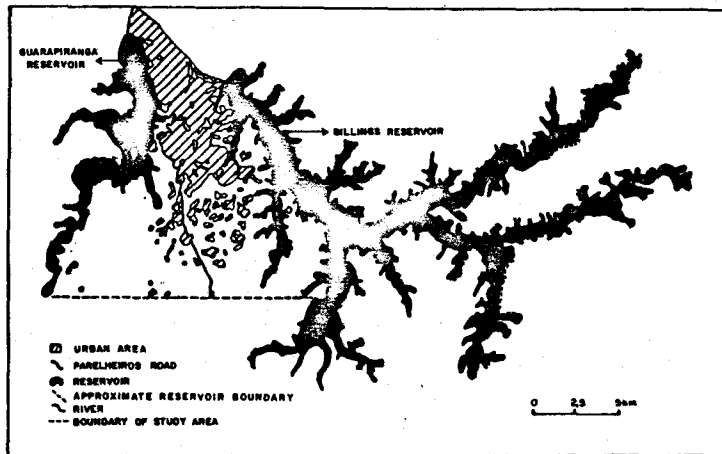Figure 2.  Urban Area Obtained from 1977 MSS Data (visual interpretation).

8.

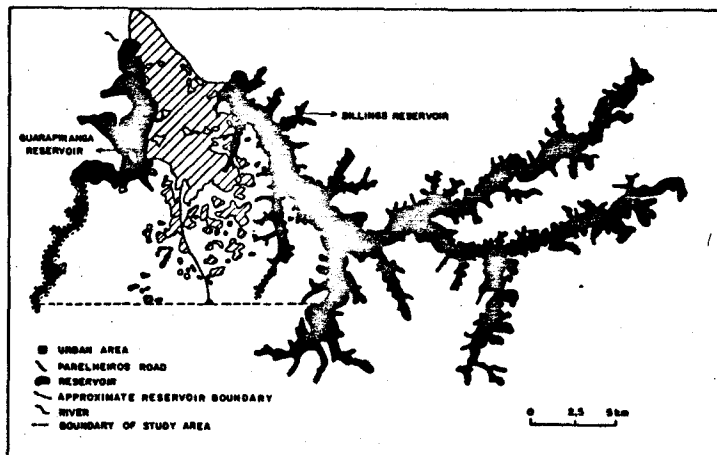Figure 3. Urban Area Obtained from 1978 MSS Data (visual interpretation).



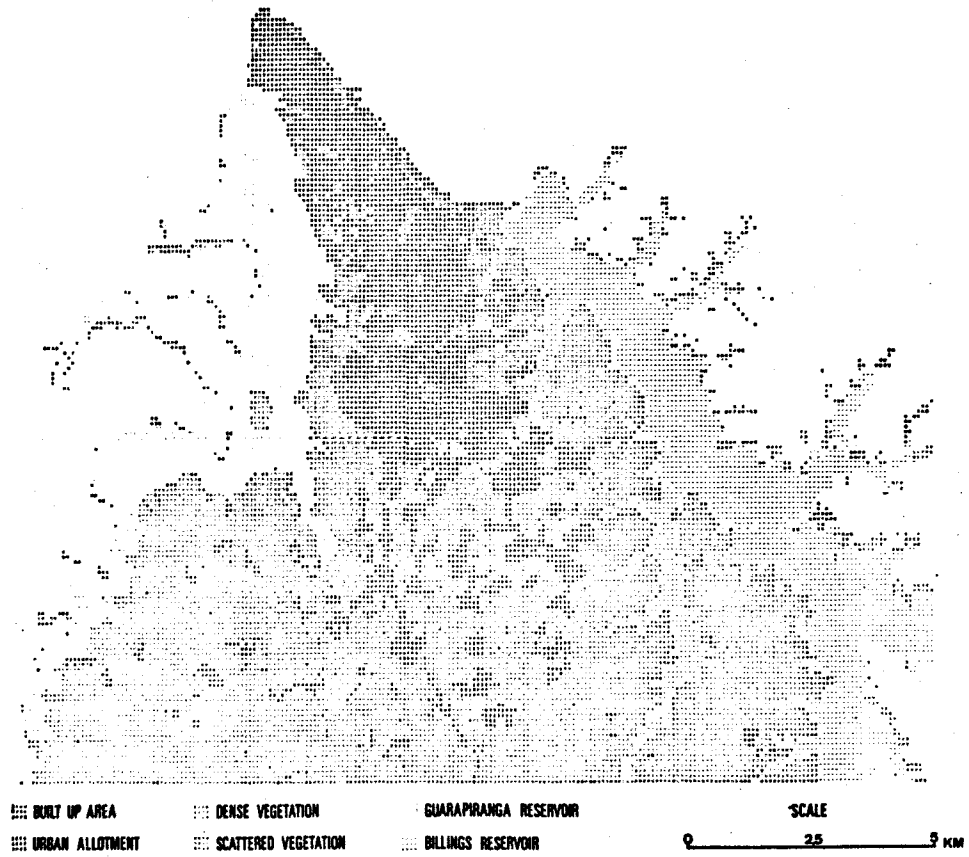Figure 4. Urban Area Obtained from 1979 MSS Data (visual interpretation).

9.

BULT UP AREA    DENSE VEGETATION    GUARAPIRANGA RESERVOIR    SCALE

URBAN ALLOTMENT    SCATTERED VEGETATION    BILLINGS RESERVOIR    0    2.5    5 KM

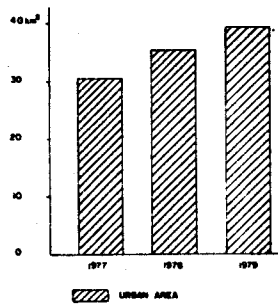Figure 5.  Urban Area Obtained from 1978 MSS Data (automatic interpretation).



Figure 6.   Total Urban Area Obtained from MSS Data
(visual interpretation).

10.