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EVALUATION OF HIGH RESOLUTION SATELLITE IMAGES FOR URBAN POPULATION ESTIMATION

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ABSTRACT

The objective of this research was to evaluate the applicability of high spatial resolution remote sensing data for the estimation of urban population in the inter census periods in the Brazilian city of São José dos Campos. Digital IKONOS-2 data were used. Data analysis was conducted using SPRING (GIS). The procedure attempted to identify intra-urban network areas with similar residential occupation features, known as homogeneous zones. Within some chosen zones, official census sectors were defined**.** The number of housing units per sector was identified in the digital IKONOS images. The population was estimated by multiplying the number of dwellings by the average per household occupancy figures obtained from census tract data. Estimates showed satisfactory results when compared to the census data, which motivated deeper analysis for the entire area of the city of São José dos Campos.

1 INTRODUCTION

According to the year 2000 demographic census the Brazilian population consists of 169,799,170 inhabitants of which 137,953,959 are in urban areas.

Figure 1 depicts Brazilian urban population growth, mainly due to a high birth rate. Presently, over 81% of the population is concentrated in urban areas, a tendency that began in the 1970's when the urban population surpassed the rural one. This increase is basically due to urban population natural growth and to the great migration process from the rural to urban environments.

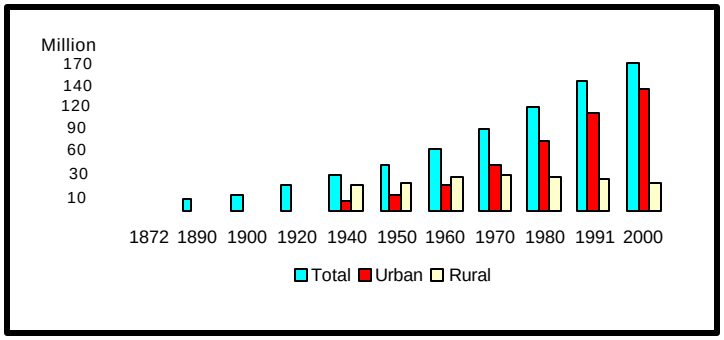

Figure 1 – Evolution of urban and rural urban Brazilian populations

The fast growth of the urban population is a major urban planning problem. Unplanned growth of the cities is also related to the lack of suitable tools to acquire useful information for urban growth control.

Demographic censuses are conducted only every ten years due to the high human, material, and financial resources involved in surveys and data analysis. Although census data are fundamental for national decisions, they are not sufficient to guide urban planning processes, given the lapse of time between data acquisition and official publication. The dynamics of Brazilian cities demand more frequent reliable, low cost surveys to attend population claims for hospital, school and recreation services.

These problems have already been raised by Kraus et al. (1974). Furthermore, city censuses are sectored according to criteria that aim at data collection rationalization without properly accounting for data analysis, as pointed out by Kurkdjian (1986). Hence, more flexible and faster inter-census surveys are necessary, with data reflecting a city's internal differentiation to support proper area selection for service and equipment installation.

Remote sensing data has been considered as a proper alternative to provide this information. Many studies have been conducted utilizing aerial photography in the development of methodology for demographic data acquisition (Hsu, (1971) ; Kraus et. al., (1974); Adeniyi, (1983); Dureau, (1992).

Using color infrared photography of a scale 1:20,000 Lindgreen (1971) attempted to estimate the number of dwelling units in four select areas of metropolitan Boston. He pointed out that from such estimates a number of additional estimates could be generated, including total population.

Manso et al. (1978) carried out studies that explored the existent relationships between urban morphological, demographic and social-economical features of residential populations, using the city São José dos Campos as a test site. The assumption was that there was a relationship between urban morphology expressed as image texture and extended family sizes.

Manso et al. (1978) applied panchromatic aerial photography to the estimation of the urban population in São José dos Campos, obtaining a 1.3% discrepancy in relation to the official data.

Aerial photography used for this purpose, involves high cost for developing countries with large territories, where the available economic resources for urban studies are scarce. Therefore, orbital remote sensing has been considered as an adequate option to provide urban population data information. Murai (1974), Lo (1995) e Chen (2002). developed studies with satisfactory results in spite of the limitations of the spatial resolutions of the sensors used (LANDSAT e SPOT).

Foresti (1978) developed a study to verify the correlation between the urban area identify by MSS-Landsat data and population size in 105 Brazilian cities. A high correlation was found between population size and urban area for small cities, but such a relationship did not hold for large cities with a high percentage of vertical occupation.

Progress in space technology has resulted in spatial and temporal improvement in data quality. Availability of high spatial resolution data from QuickBird (0.6m) and Ikonos (1m), has stimulated the application of remote sensing to urban studies. It is expected that the number of remote sensing data applications for urban system studies will increase as more accurate information becomes available and better cost-benefit ratio is attained.
The objective of the research presented in this paper is to apply panchromatic and color Ikonos-2 images to urban population estimation.

The results of this research can be applied to inter census population estimation. Selected sectors of São José dos Campos city were used as test sites. The city is located in São Paulo State at 23º 10' S and 45º 50' W, situated between the two major Brazilian metropoli, Rio de Janeiro and São Paulo.

2 MATERIALS

Panchromatic digital Ikonos image and color product from multispectral Ikonos image fusion acquired on 10 september 2000 and 13 october 2000 respectively, were used for this research. Digital orthophotographs acquired in the year 2000, with 0.6m spatial resolution of a scale 1: 30,000, were used to develop photo-interpretation keys. Census sectors and associated demographic data for the year 2000 (IBGE, 2000) were utilized to define test areas. Data integration and modeling were conducted with SPRING software for image processing and the analysis of geographic information.

3 METHODOLOGY

Ikonos images were first geometrically corrected using SPRING-GIS. Five census sectors were selected for the development of this research, corresponding to the residential zones with single family residences and different socioeconomic characteristics defined by Manso (1979).

Figure 2 represents two of the sectors analyzed that show different spatial and socioeconomic organizational characteristics.

Figure 2 . Ikonos image showing two sectors analyzed

The test areas were field checked in order to develop the interpretation keys to be applied in the image interpretation. The observed features were: plot size, total building area, roof types , and number of detached and semidetached houses.

The next step was to count the number of dwelling units per sector in Ikonos images. Then, the average number of persons per household of each sector was calculated by dividing the total population by the total number of dwelling units per sector.

The population of each sector was estimated by multiplying the number of dwellings by the average per household occupancy ratio extracted from census tracts data, according to the following equation:

$$P = N \cdot M$$

Where: P = sector population.
N = Total number of dwelling units identified in Ikonos image.
M = average number of persons per household (from census data).

Differences between estimates and census data were calculated.

4 RESULTS

The comparison of population size estimates from Ikonos images and census data are shown in table 1.

Table 1 – Population estimates from different sample sectors

Sample Sectors	Sector 122 (Jd. Apolo)		Sector 315 (Jd. Motorama)		Sector 62 (Jd. N.Michigan)		Sector 38 (Vila Maria)		Sector 269 (Jd. Granja)	
IKONOS IMAGE	PI	CI	PI	CI	PI	CI	PI	CI	PI	CI
Estimated POP.	609	605	608	605	639	636	609	612	954	928
IBGE pop.	588		608		628		576		872	
Error (%)	4 (+)	3 (+)	0	0	2 (+)	1 (+)	6 (+)	6 (+)	9 (+)	6 (+)

PI = Ikonos Panchromatic Images
CI = Ikonos Color Images

Percentage errors presented in the table data were relatively low, except for sectors 269 and 38.

Sector 269 is inhabited by a low-income population, where plots are frequently occupied by a main dwelling and a smaller unattached dwelling unit in the backyard which is often rented out to increase the homeowner's income , or occupied by family members, such as adult children and their families. This social phenomenon is characteristic of working class neighborhoods in Brazil. Field check normally confirmed its practice, so all unattached structures were counted as dwelling units. This aspect may have led to overestimation of dwelling numbers.

According to IBGE census data (2000), there are a large number of unoccupied houses in this neighborhood, which also led to population overestimation.

Small-sized irregular shaped plots, resulting from spontaneous urban growth without prior street planning can explain the errors associated to sector 38, an old, inner city neighborhood.

Difficulties in building counts in that sector arose from the difficulty to precisely determine if homes placed in the middle of blocks should be considered independent units or residential extensions. The lack of identification of household entranceways (inside the blocks) also impaired data analysis.

Table 1 shows that population overestimation resulted from practically all image products that were analyzed. Mean error obtained for population estimation was 4 % for Ikonos panchromatic images and 3 % for Ikonos color images. The best result obtained with the color image could be associated to the fact that this product contains the spatial resolution of the panchromatic data and the spectral resolution of the multispectral data.

Many factors affected the results, predominantly the great variability of form, type and material of the roof and the differences in type and size of residential structures within each sector.

Due to the high internal spatial heterogeneity of Brazilian cities it would be necessary to analyze a larger data set of urban sectors to achieve better reliability of the results.

5 CONCLUSION

The results obtained show the potential of IKONOS images to estimate inter census population size in Brazilian cities, as well as the use of these images as an additional tool for demographic census surveys. The synoptic view of these images could guide field surveys for demographic censuses and perhaps increasing the accuracy of data obtained.

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