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**URBAN MANAGEMENT USING REMOTE SENSING  
TECHNIQUES**

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## Urban management using remote sensing techniques

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**Abstract.** Urban growth in Brazil is characterized by a lack of appropriate planning. Besides the current social organization, this is due to high rates of demographic growth induced by the natural increase rate of urban population, transfer of rural population to urban areas and migration from poorer to richer regions. The fast growth rates of urban population is therefore one of the main problems for effective urban management in Brazil. Disorganized growth of cities is also related to the lack of adequate tools to obtain useful information for urban management. Orbital remote sensing has been appointed to be an adequate alternative to provide such information. The possibility of fast and low cost monitoring of urban areas has been improved by the fine spatial resolution of orbital remote sensing products, as well as, by better data availability provided through the larger number of existing remote sensing platforms. This work has the objective of presenting the state of the art of the application of orbital remote sensing to urban management in Brazil. It briefly describes some of the studies carried out at the National Institute for Space Research-INPE. Several digital processing techniques have been used, such as registration of multitemporal images and IHS transformation. Integrated studies were also conducted in order to understand the process of urban growth in view of a broader land use pattern and to analyze the relationship of the urbanization process to environmental conditions.

### I - Introduction

According to the last demographic census, carried out in 1991, the Brazilian population is 146.825.475 inhabitants.

Demographic census data were first collected in 1872. The graphical representation from 1940 onward (figure 1) indicates a progressive increase in population which is mainly due to the high birth rate.

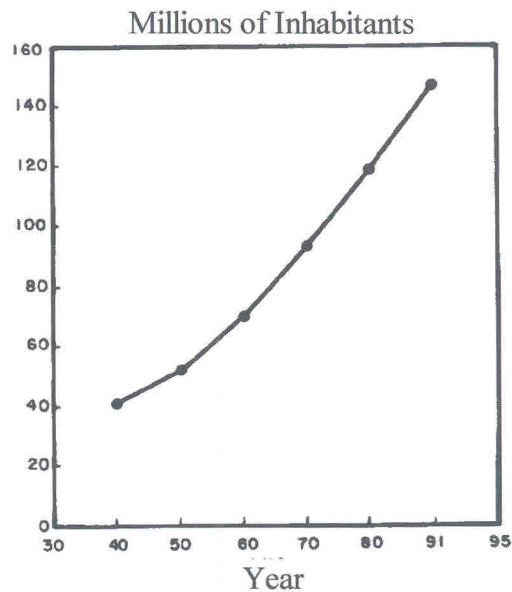


Figure 1 - Evolution of the Brazilian population (1940-1991)  
Source: IBGE (1991), p.13

Currently, 75.9% of the Brazilian population is concentrated in urban areas, as a consequence of a trend that was initiated in the sixties when urban population became larger than the rural population (figure 2). This growth is basically due to the natural increase rate in urban population and to the strong migratory process from rural to the urban areas.

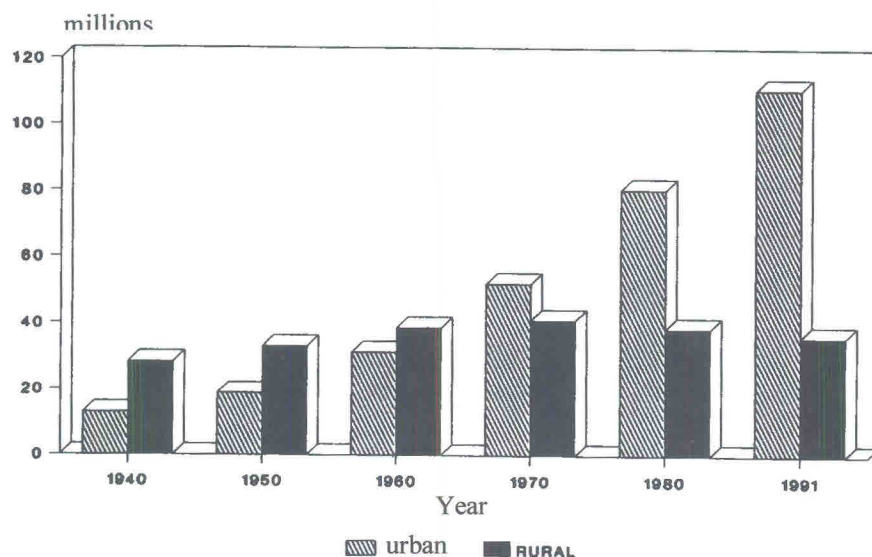


Figure 2 - Urban and rural populations during the period of 1940 to 1991  
Source IBGE (1991), p.19

The Brazilian urban network presents eight cities whose population is larger than 1,000,000 inhabitants (figure 3). The city of São Paulo is by far the largest one with 9,646,185 inhabitants. Metropolitan area of São Paulo is the second largest one in the world. It has 16,232,462 inhabitants of which 97.98% is considered urban.



Figure 3 - Brazilian cities with population larger than 1,000,000 inhabitants.

Brazilian cities are progressively moving towards a reduction in quality of life for their inhabitants. Lack of dwellings, infra-structure and basic services (sanitation, transportation, education and health) are evident problems in all large cities. Pollution, floods, land slides, reduced green areas, disorganization of the urban network, violence and heavy traffic are also major problems in these cities.

The growth of Brazilian cities has been disorganized and lacks adequate planning. This is caused by, the high rate of demographic increase due to natural increase of urban population, the migration of rural populations to urban areas and from poor regions to richer ones, as well as, the current social structure. All these factors impose difficulties for proper urban management.

The high rates of urbanization, which have increased in the last decades, have produced population clusters where socioeconomic conditions and strong land speculation aggravate the disastrous effects of this disorganized occupation.

Besides problems in the organization of the intra-urban space caused by the current social structure characterized by an unbalanced distribution of income (Vieira and Kurkdjian, 1993), the urban development in Brazilian cities, in general, takes place without much consideration to their physical environment. This causes serious consequences to the quality of life of their population at short, medium and long terms. Urban settlements are made in places with severe restriction to urban development, such as, steep slopes and flood prone areas. The low income population is often localized on public land or in ecologically fragile areas as a function of land value. Presently it is noticed that urban growth occurs also in high risk areas such as hill and floodplains. The poorest strata of the population also tends to agglomerate in empty urban spaces, giving rise to slums.



Another characteristic associated with the growth of the cities is the occurrence of illegal settlements. Such illegal settlements do not pay taxes and, therefore, reduce revenues for urban infrastructure improvement. These settlements often occupy risk areas and areas protected by environmental legislation due to the lack of proper fiscalization. Therefore, it is necessary to study and analyze urban land use in relation to its physical environment through multitemporal and integrated studies.

The disorganized growth of cities is also related to the lack of instruments to obtain useful information for urban management. There is also a lack of trained staff and necessary funds for creation of efficient urban management systems. In this manner, there is practically no updated information about urban areas.

Due to limited financial resources, urban planning and monitoring has not been efficiently performed through conventional methods, such as, field work and aerial photo interpretation. Furthermore, aerial surveys which can provide information to the planning process, are not carried out on regular basis.

It has been pointed out that orbital remote sensing data could be used as an alternative to aerial photography to provide information for urban management.

Remote sensing data are especially useful to obtain information related to the physico-territorial aspects of one area. They are also highly relevant for developing countries with large area and where there is a lack of systematic spatial information.

According to Kurkdjian (1993) orbital remote sensing products present some characteristics that are applicable to urban environmental studies:

a) Multispectral characteristics - products are generated in different spectral bands, each one suited for specific thematic application to discriminate particular targets;

b) Integrating characteristic - color composites obtained from products acquired in different spectral bands allow an integrated view of the urban space in a more complete way than the one offered by its individual bands;

c) Synoptic view characteristic - a single frame of MSS/Landsat and TM/ Landsat sensors covers an area of 185 x 185 km and the frame of the sensor HRV/Spot covers an area of 60 x 60 km. Therefore, a single image provides an observation of the urban space and its surroundings allowing the understanding of the structuring of this space;

d) Multi-scale characteristic - orbital images may be presented in different scales (from 1:1,000,000 to 1:50,000 in photographic prints). On image processing monitors, images are displayed in full resolution or larger scales. The opportunity of working at different scales allows the photointerpreter to work with a synoptic view of the urban space and its surroundings and to reach a detailed view, which is only limited by the spatial resolution of the sensor, that is 80 m for the MSS/Landsat; 30 m for the TM/Landsat; 20 m for HRV/Spot on XS mode and 10 m for the HRV/Spot on PAN mode;

e) Geometric characteristic - within the scale limits, orbital remote sensing products allow the elaboration of thematic maps which meet the requirement for geometric mapping accuracy. In this case, costly restitution tasks are avoided.

f) Multitemporal characteristic - due to the frequent satellite revisit and availability of archive data (available since 1973 for MSS/Landsat) change detection and analysis of urban space dynamic may be conducted .

g) Digital characteristic - the numerical format of orbital images is an advantage over conventional aerial photography for urban planning. Digital image processing allows the application of pre-processing techniques (radiometric and geometric corrections), enhancement techniques (improvement of the visual quality of the images), classification techniques (automatic pattern recognition) and the integration of multitemporal or multisensors data.

h) Hybrid characteristic - the numerical format of orbital images also allows the generation of hybrid remote sensing products which are extremely useful to urban studies that require fine spatial and spectral resolutions. Data from different sensors are integrated to generate new composed image. For example, integrating TM/Landsat and HVR/Spot images, a color composite image may be generated with a spatial resolution of 10 m. Foresti et al. (1987) and Kurkdjian et al (1989) presented the analysis of such products for the improvement of the interpretation of intra-urban aspects.

Improved spatial resolution of orbital remote sensing products and the larger number of orbital platforms presently in operation have greatly increased the possibility of urban monitoring in a relatively short period of time at low cost. Therefore, it is evident that orbital remote sensing is a useful tool for the analysis of urban areas.

## II - Application of Orbital Remote Sensing Data to Urban Management

According to Kurkdjian (1993) there are two majors applications of remote sensing to urban planning: the first one, oriented toward the understanding and action about the urban space in general and its relationships with broader municipal and regional spaces, and the second one, related to intra-urban studies. The latter is more constrained by spatial resolution of orbital products.

In relation to the general urban system, its relationships with the physical environment that supports it and with the broader municipal and regional spaces, the utility of remote sensing associated to surveying work is extremely large. Within this line the analysis of the urban growth may be approached with the use of orbital remote sensing or the integration of multi-source data.

The structure analysis of the urban space and the dynamics of the urban expansion in face of alternative scenarios of land use may be conducted with orbital images with a better cost/benefit ratio than with conventional methods. Some results obtained for brazilian cities have shown the utility of orbital images and digital processing for the analysis of urban growth. Studies conducted by Oliveira et al. (1984) and Pereira et al. (1988), in the urban areas of Brasilia and São José dos Campos, respectively, demonstrated that MSS/Landsat data are useful for urban growth monitoring using multirate image registration technique (Figure 4).





Figure 4 - Brasília - Change Detection 6/26/73 - 06/17/83  
Source Oliveira (1984), p.15

The authors concluded that the multirate image registration technique associated with the use of adequate colors (RG B) produced a powerful tool for the assessment of trends in urban growth considering its spatial and temporal dimensions.

Other digital image processing techniques have been utilized in order to improve image quality and to increase the information content that can be retrieved from these products for urban growth studies.

Efficiency of hybrid products obtained through the use of IHS transformation has been demonstrated. Such hybrid products have been utilized to improve the mapping accuracy of urban areas (Vergara, 1994) as well as in some intra-urban studies (Figure 5).

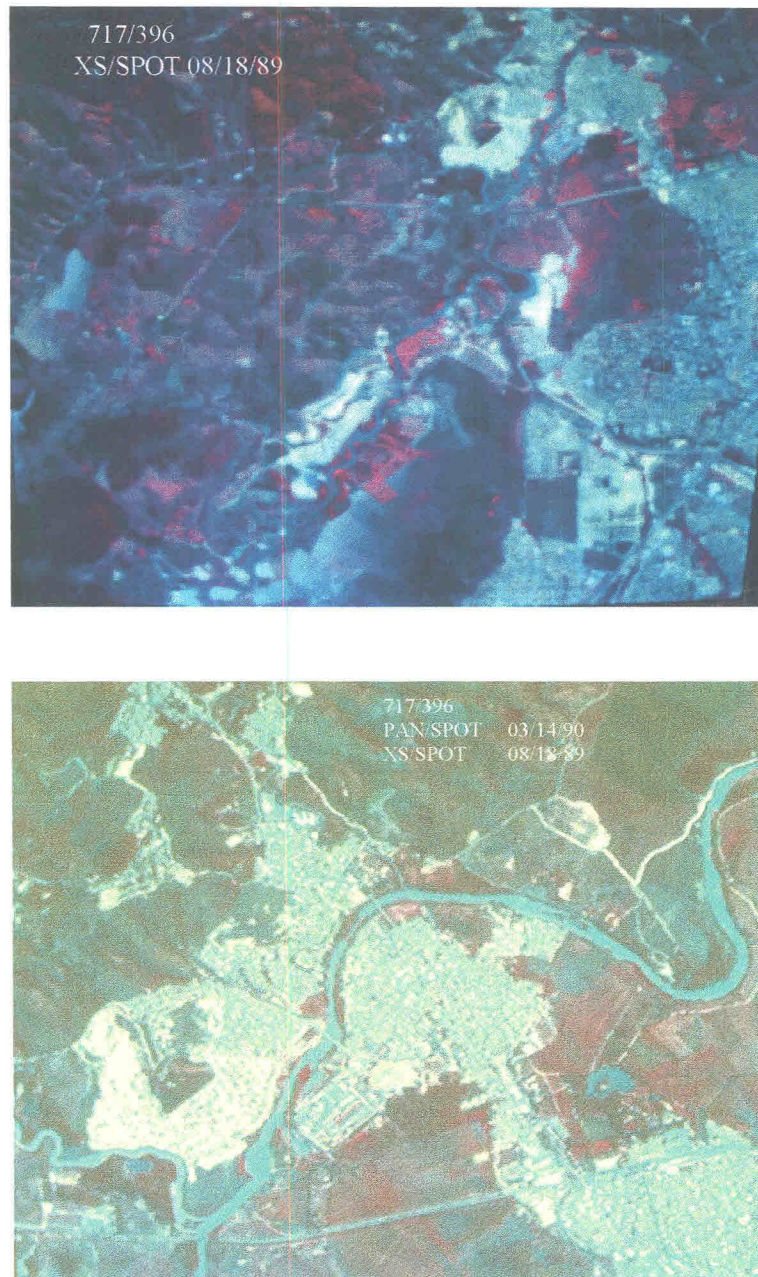


Figure 5 -XS/Spot and Hybrid product (PAN/Spot and XS/Spot). Test Area - São José dos Campos-SP  
Source: Vergara (1994), p.77

Recently, integrated studies have been conducted using orbital remote sensing data to better understand the process of urban growth in a broader context of land use and land occupation, with emphasis in the analysis of the suitability of the physical environment to the urbanization process. An example of such studies is the Project MAVALE (Kurkdjian et al. 1992) where the Macro zoning of the land use for the Paraíba Valley and Northern Coast Region of the State of São Paulo, Brazil (18,111 km<sup>2</sup>), was performed using TM/Landsat and HRV/SPOT images for the year of 1988. Visual interpretation and digital image processing were conducted at the scales 1:250,000, 1:100,000 and 1:50,000 for the environmental diagnosis of these region.



Geological, geomorphological and ground water information were extracted from remote sensing products and were used to elaborate maps of land use suitability, areas favorable for engineering works, areas for urban expansion and areas with risks of geologic hazard. This information, associated with land use/land cover maps and socio-economic diagnosis, allowed the elaboration of maps that provide guidelines for regional land use policies. The analysis of the urban expansion was made at the scale of 1:50,000, utilizing TM/Landsat and HRV/SPOT images from the period of 1977 to 1988. Visual analysis was conducted for these images based on conventional photo-interpretation criteria. One of the determinant factors in the definition of the city network and of the delineation of their shape and expansion was the relief which restricted the concentration of the cities to flat terrain areas. Urban areas are found mostly in regions of flat hills with declivity of 10% to 13%. Comparing the map of urban expansion from 1977 to 1988 with the land use map (1977) it was verified that most of the urban growth took place over areas formerly covered with pastures. It was detected also that urban expansion was taking place in floodplains and areas with rough relief.

Comparing the urban expansion map with the land use suitability map one noticed that urban expansion occurred in areas suitable for agricultural use. Areas favorable for urban expansion are also suitable for agricultural activity and the competition between urban and agricultural development takes place at restricted areas. In this sense, the extensive scattered and discontinuous form of urban development implies not only in costly infra-structure implantation but also in waste of natural resources.

Conclusions of the MAVALE project in relation to urban area are: to encourage urban occupation in suitable areas according to the map of areas favorable for engineering works and urban expansion; to intensify the agricultural use and to increase its diversity on the suitable areas for agricultural activities; to control urban expansion to avoid the creation of intra-urban empty spaces and conurbation, and finally, to inhibit urban occupation in floodplains.

These results were used to support the elaboration of the Master Plan of some of the municipalities of the studied regions comprised in the project area. As an example, the municipality of São José dos Campos has elaborated within its Master Plan a Municipal Macrozonning. This plan defines, among others, the urban land use, organized it hierarchically for civil development through the establishment of categories of urban occupation taking into account its demographic density.

These studies demonstrated the usefulness of orbital remote sensing data for urban management and showed the importance of environmental issues to city planning.

### III - Conclusions

The scope of the applications of remote sensing to urban planning has grown in different directions of action in recent years.

Urban planning is an interdisciplinary task where environmental problems occur intensely and professionals with different specialities are required.

Orbital sensors are increasingly improving their spatial and spectral resolution and stimulating the development of new applications relevant to urban planning.