IMPROVING URBAN DATA COLLECTION IN DEVELOPING COUNTRIES WITH REMOTE SENSING TECHNIQUES

T.C. Veiga
International Institute
for Aerospace Survey and Earth Sciences
ITC
P.O.Box 6, 7500 AA Enschede
The Netherlands

ABSTRACT

The problems of data collection for urban planning and management in Developing Countries are largely due to lack of recent information, to the time consumed gathering data, and to the difficulties of collating data from different sources.

Depending on the kind of data required, aerial photographs and satellite images can be a useful source of information, especially for physical planning purposes. The most common application of airphoto and satellite image interpretation of urban areas is for land-use surveying and detection of settlement growth. Other possibilities must still be explored. Some applications are described and illustrated in this paper.

RESUMO

Os problemas referentes à coleta de dados a serem utilizados no planejamento e administração de municipios, nos paises em desenvolvimento, devem-se basicamente à falta de informações atualizadas, ao longo tempo dispendido na coleta e preparo dessas informações e às dificuldades de combinar-se os dados produzidos pelas diversas fontes.

Dependendo do tipo de dado a ser utilizado, fotografias aéreas e imagens de satelite podem ser uma pratica fonte de informações, especialmente para a aplicação em planejamento fisico e territorial. A utilização mais comum da interpretação de fotografias aéreas e de imagens de satelite em áreas urbanas é para o levantamento de usos do solo e para analizar o crescimento das cidades. Existem ainda outras possibilidades a serem exploradas, algumas das quais são descritas e ilustradas no presente artigo.

1. INTRODUCTION

The fast growth of cities and the diffusion of urbanization are phenomena which can be detected all around the world, especially in developing countries. All sorts of plans are being drawn up for controlling, implementing, monitoring and administering projects which aim at enabling cities to cope with this problem. These plans must be backed by wide-ranging and complex information. Collecting this information in developing countries is one of the biggest tasks of planners and planning agencies.

The "Program of Technical Assistance to the Municipalities for Elaboration of Urban Development Plans", carried out by the Government of Rio Grande do Sul Estate, Brazil, pointed out in the document "Guidelines for Research"(ESTADO,1985) the need of specific data for analysis for planning. The document recommends which data is necessary and gives the sources that can provide. It is summarized in Fig. 1.

Social-economic data related to demography, economic base and political, administrative and planning processes is generally obtained from municipal and census records. For physical planning purposes it is necessary to collect more specific spatial information about the city itself, which should be as accurate as possible.

The problems presented by this are in the lack of recent information, the long, time-consuming process of data collection, and the difficulty of relating data from different sources when the information does not refer to the same period or same geographic base. By the time the information has been processed for analysis, it is already outdated.

The Municipality of Bento Gonçalves-RS, Brazil, is preparing a new Development Plan based on the "Guidelines" mentioned above. And, with assistance from the Superintendency of Urban Development and Municipal Administration, is hoping to develop efficient procedures for collecting and processing data in the future.

Aerial photographic coverage of the urban area at a scale of 1:8.000 was ordered by the municipality for photogrammetric and cadastral purposes. The airphotos, taken in October 1986, were available less then two months later; the photogrammetric and cadastral base maps, almost one year later.

The same photographs could have been used during this time for obtaining much of the information needed in the first stages of drawing up the development plan, which would have reduced the time spent on collecting data by conventional methods as well as the costs of a detailed census survey. How this can be done, and with a good margin of accuracy, is the subject of this paper.

2. POSSIBILITIES OF MAKING USE OF REMOTE SENSING INTERPRETATION(RSI)

Using the data on urban space specified in the" Guidelines for Research" (Fig. 1) as a reference, it is possible to show the applicability of airphoto and satellite image interpretation as a tool for helping survey as part of planning procedures.

Having defined the object of analysis, a first assessment of the urban area can be made by the interpretation of the most significant features on the small-scale air photographs (more than 1:10.000 for urban areas) and on the satellite printed images. Natural and build-up aspects will allow a general evaluation of the occupation process and the best alternatives for expansion according to the site characteristics. Contour lines and steep slopes; river, water bodies and flooding areas; roads and railways; forests and constraints for expansion can be identified by airphoto or satellite image interpretation and shown on thematic maps. In this first stage it is already possible to make suitability studies for site selection, combining the information obtained with data on soil, wind, and other relevant aspects.

The analysis of constraints, which influence the occupation process and which produce the current pattern of urban space, enables the tendencies for expansion of the urban area to be predicted. Data on the most recent built-up areas over, say, a 5 or 10 year period, can be obtained from the interpretation of sequential aerial photographs or satellite images from different periods. To classify these new areas it will be necessary, however, to check the kind of infrastructure which is present, the legal status of the area, and the original land-use.

The transformation that occurs in the fringe area, especially in developing countries, is commonly associated with agricultural land being taken over by illegal settlements, unplanned areas, squatter/slum areas, housing schemes and scattered industrial and warehouse sites.

In this case, information about vacant land, combined with other relevant information such as land-ownership and price per square metre will be not only a tool for planning future land use but also an important element for understanding the forces which influence the occupation, the activities distribution and the social-economic patterns of the city. Furthermore, the amount of green areas, public squares, open spaces and distribution of trees in the city can be surveyed and itemized using large scale airphoto interpretation (less than 1:10.000 for urban areas).

Road networks are one of the features that define how urban activities are linked and in which direction they are expanding. By analyzing the road hierarchy together with the distribution of urban land-use it is possible to define the points of traffic generation such as the commercial areas along the main roads. Large scale air photographs can be used to identify which roads are paved, to estimate the number of unpaved ones, and to determine whether they are served by street lighting.

The second step concerns a survey of the dominant land uses in the city as a whole or per zone. The "Guidelines for Research" bases the collection of this kind of data only on field survey and only at the levels of zones, blocks, streets, plots, buildings, and dwellings. For a general view of the distribution of these activities, depending on whether the scale of the aerial photographs are large or small, it will be possible to detect vacant plots and buildings under construction, the number of buildings per plot and number of floors per building, main activities per plot or per block such as industrial (big or small industries), commercial (shops, workshops, garages, offices or commercial centers) and residential or mixed (single-family or multi-family housing combined or not with other activities). Form and type of dwellings, number of units per plot, schools, hospitals, recreational areas and buildings or sites with cultural or historical value can also be identified on large scale photographs. This is particularly useful for analyzing catchment areas and relating this data to population figures. Depending on the scale it is also possible to collect more detailed information about dwellings and activities and about urban features such as telephone booths, power stations, water towers, traffic control, etc.

Measurements on the photographs will enable estimates of:

- -area of city-blocks and areas occupied by the activities;
- -population per block (by multiplying the estimated number of residential dwellings with the number of inhabitants per dwelling obtained from recent census data);
- -population and housing densities per block and zone.

With the help of computer-assisted systems the information can be stored, processed, combined with field-work data and illustrated in a series of thematic maps including:

- -Land-use: containing all the activities which occupy the urban space;
- -Zoning: indicating the predominant uses in a zone;
- -Density: showing the quantitative distribution of inhabitants per block, zone, or other selected unit;
- -Location of special features: housing schemes, slum/squatter areas,institutional buildings, public land, etc.

A third step will be to make regular use of sequential aerial photographs and satellite images for monitoring spatial growth (for example every five years) of unplanned large squatter/slum areas, illegal land subdivision on the urban fringe, and the general expansion of the city.

An example based on the research carried out for my thesis illustrates some of these possibilities.

3. EXAMPLE: DETECTION OF HUMAN SETTLEMENTS GROWTH USING SATELLITE IMAGES FROM DIFFERENT PERIODS.

3.1. Introduction

Bento Gonçalves is situated in the south of Brazil, in the state of Rio Grande do Sul, in a region characterized by a mountainous landscape with steep slopes and many valleys along the river beds.

Having only aerial photographs from 1986, it was not possible to evaluate the growth from the publication of the previous Master Plan until now. The satellite images replaced the airphotos in terms of regional and general analysis of the urban space of Bento Gonçalves.

The availability of data from MSS images since the launch in 1972 of the first satellite of LANDSAT series in Brazil enables recovery of information at orbital level in a period of time significant for the evaluation of the tendencies and alterations of the urban spatial organization.

Based on the studies carried out for SPOT images interpretation (POLLÉ, 1988), MSS and TM LANDSAT images were used for monitoring the urban growth of Bento Gonçalves in two different periods: 1973 and 1986.

3.2. Aim and Practical application

Within the last two decades, a number of studies in developing countries have demonstrated that remote sensing techniques are able to provide cost-effective, timely and efficient information for urban planning and management.

Information on the growth of human settlements is essential where the economic and social development of a city - or a region - is concerned.

The size of urban areas in different periods can be measured by using methods and techniques which enable also the calculation of the gross urban density.

An overview of the main land features can be used for preliminary planning of the extension of the urban area as well as for regional planning purposes.

The aim of this study is to test the possibilities of using Landsat satellite images as a source of thematic data for guiding the physical planning of the region, and to stress the importance of using remote sensing data for city planning in developing countries.

It has, also, the intention of giving an overview of the main features which can be constraints on expansion: valleys, depressions, river beds, steep slopes, drainage lines.

3.3. Materials

This study used black & white aerial photographs at the scale 1:8.000 and MSS/LANDSAT (bands 4,5,6,7) as well as TM/LANDSAT (bands 2,3,4) false colour composites, processed at ITC Image Processing Laboratory (IPL) from CCT's (computer compatible tapes) obtained at the Institute of Spatial Research - INPE, São José dos Campos-SP, Brazil.

The 1:100.000 photographic enlargements were made from diapositive false colour composites in the scale 1:800.000 (MSS) and 1:600.000 (TM). A cartographic base map on scale 1:250.000 was also used. (Table 2).

3.4. Definitions

"Urban area" is a land use class based on the utilization of the land for activities which are different from rural or natural environment. It is limited by the detection of the differences in land uses mainly built-up and non built-up areas.

It is represented on the satellite image as a group of pixels (picture elements) with a typical combination of tone, colour, and texture (or pattern) which gives a continuous bluish tint to the compact built-up area. This is a generalization for defining human settlements in contrast with rural land.

Picture element or pixel is the representation of a scene element in the picture; scene element is the portion of the earth "viewed" by the sensor (80x80 m on MSS and 30x30 on TM). The sharpness of the final printed image depends of the choice of the pixel size and the enlargement.

3.5. Interpretation procedures

-enlargement of a 1:250.000 map of the region from 1981. The map is based on the topographical survey made by the Engineering Department of the Brazilian Army. The map is outdated and it does not show the city of Carlos Barbosa but it is probably more geometrically accurate than the satellite printed images. Some main features have been selected on the map for positioning the cities on the satellite images: main roads, lakes, rivers, etc.;

-distances have been measured in the map and on the satellite printed images in order to calculate the scales;

-printed images were analyzed for familiarizing with the tones, colours and textures and for identifying objects like airports, stadium, rivers, etc.

-delineation of the urban areas on overlays superimposed to the MSS and TM printed images with fiducial marks for further comparisons.

-the two interpretations were digitized, measured, compared and checked with the photo interpretation map for the case of Bento Gonçalves urban area.

3.6. Interpretation results

-The delineation of the urban area of the region where Bento Gonçalves is located was done on a MSS and TM false colour composites scale 1:100.000. On these images, urban objects can not be recognized by their shape and size, except for some large ones like airport runways, football stadiums and water bodies (Fig. 2 and 3);

-The MSS printed images are less sharp than the TM but rivers and roads are still clearly to be seen and the contrast between built-up and non built-up areas is better defined;

-There are large bluish areas on the images which were not settlements but either vineyards out of season or clouds. The bluish tone of the clouds is mixed with white spots and the texture is more smooth. The vineyards and agriculture areas differ from the compact urban and cloudy areas because of a more light bluish tone and a scattered pattern.

-The average growth of the urban areas in this 13 years period is about 57%. Bento Gonçalves (64%) and Farroupilha (63%) experienced the fastest growth. The growth percentage of Carlos Barbosa is not considered because the built-up area does not appear completely on the MSS enlargement (Fig. 4, table 2).

-The occupation process of the Bento Gonçalves site is limited by the topographic constraints, especially the Western part. The expansion occurred mainly in the directions North-South and East. The tendency of expansion will remain in this directions where the slopes are not so steep (Figure 6).

-The difference between the interpretation of built-up area in the aerial photographs (API/86) and satellite printed images (TM/86) is about 520 ha (Table 3). This is due to the generalization which had to be made for built-up areas in the satellite images interpretation.

3.7- **Conclusions**

-Satellite images are a useful data source for monitoring changes on urban areas and for detecting human settlements growth.

-The use of this study can be either for map updating and detection of the cities extensions.

-These extensions can be selected for further aerial photographic missions.

-Special training is required particularly with regard to the identification of topographical and geological features like drainage network and watersheds.

-Possible detection of new built-up areas, but they are too small for comparison with the continuous urban "mancha" (spot);

-Field-check and aerial photographs are important tools for complementing the satellite printed image interpretation in terms of the identification of urban objects like stadiums and airport runways.

-It is impossible to recognize individual buildings on the satellite images unless they have special features like the football stadium.

-Specific combination of the differences in tone, colour and texture are the main indicators for identifying urban and non urban areas on the images.

-Satellite remote sensing in the format LANDSAT, specially TM format, with 30m resolution has practical application in the array of tools available for collecting data from different periods, at the same base, for the analysis of fast-growing cities.

4. CONCLUDING REMARKS

-Remote Sensing interpretation is certainly a tool for improving data collection in developing countries, especially in combination with computer assisted methods for data storage, processing, and mapping. Developments in the field of personal computers are lowering the cost threshold for computerization and the techniques for gathering information using remote sensing interpretation are being innovated. Satellite images with higher resolution are also available for regional and urban studies.

-Remote Sensing interpretation is by itself a phase of urban survey and planning because it is a less time-consuming and less costly process, especially if the aerial photographs and the satellite images already exist. Like Bento Gonçalves, other Municipalities may already have airphoto coverage of their areas and are not aware of the possibilities of using satellite images combined with them as a source of information about urban space or urban features.

-The possibilities of the use of remote sensing interpretation techniques for improving urban data collection have not yet been fully explored and are not restricted to what has been summarized in this paper. Other studies are at present being carried out and others may bring new perspectives for more accurate and precise survey results. The accuracy of the information is essential in order to give the necessary credibility to the results and their application in urban planning and management.

-Aerial photographic and satellite coverage of urban and rural areas in Brazil, for example, have been largely used for photogrammetry, geological and agricultural surveys, and cadastral work. The application of remote sensing imagery in urban planning, mainly for improving data collection, gives planners a new instrument for analysis and for gathering necessary information about the physical characteristics of urban space in a short period of time. It can also be, for municipalities, an innovation in urban management when sequential series of aerial photographs and satellite images taken over a long time-span are applied for monitoring city-growth.

-The application of remote sensing as a main source of data for the analysis of the urban area of Bento Gonçalves-RS, Brazil, for planning and monitoring the development of the city, is the purpose of an ongoing MSc research work to which the present paper is an initial contribution.

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URBAN ASPECTS FOR SURVEYING

ASPECTS	DESCRIPTION	SOURCES CONVENTIONAL	 REM.SEN.
SURVEY AREA	URBAN AREA	MUNICIPALITY	SII
URBAN PERIMETER	BOUNDARY	MUNICIPALITY	SII/API
URBAN SITE	TOPOGRAPHY	MUNICIPALITY,	
	HYDROGRAPHY	STATE, PUBLIC	
	CIRCULATION	SERVICES	
	FLOODING AREAS	COMPANIES AND	
	SLOPES > 30%	ARMY	SII/API
	VEGETATION		
	WINDS		-
	SOIL TYPES		
	MAIN PIPES		
	HIGH VOLTAGE		
LAND USE	ACTIVITIES	FIELD	SII/API
		SURVEY	
OCCUPATION	CONSTRAINTS	MUNICIPALITY,	
PROCESS	BUILDING < 5 yrs	AND HOUSING,	
	PLOTTING < 5 yrs	REAL ESTATE,	
	HOUSING SCHEMES	AND BUILDING	SII/API
	SLUMS/SQUATTERS	COMPANIES	
	INDUSTRIAL AREAS		
	SHOPPING AREAS		
REAL ESTATE	VACANT LAND	REAL ESTATE	SII/API
MARKET	PLOTS PRICE / m2	COMPANIES	-
	PUBLIC LAND		-
CULTURAL	BUILDINGS/SITES	MUNICIPALITY	
PATRIMONY	ORIGINAL USE	AND POPULATION	API
	PRESENT USE	ENQUIRE	
	CONSERVATION		-
	PRESERVATION		-
	VALUE LEVEL		-
	PRESERVED AREAS		-
ROADS	MAIN ACCESSES	MUNICIPALITY	
NETWORK	HIERARCHY	AND PUBLIC	
SYSTEM	WIDTHS	SERVICES	SII/API
	NODES	COMPANIES	
	PARKING		
	MAIN ROUTES		
	CONFLICT POINTS		
INFRASTRUCTURE	PAVED ROADS	MUNICIPALITY	
LAND FACILITIES	TREES/SQUARES	AND PUBLIC	SII/API
	STREET LIGHTNING	SERVICES	
	TELEPHONE	COMPANIES	-
	POWER		-
	SEWERAGE		-
	DRAINAGE		-
	GARBAGE		-
	TRANSPORTATION		-
	TRAFFIC SIGNALS		-
	FIRE PROTECTION		-
URBAN	EDUCATION	MUNICIPALITY	
EQUIPMENTS	RECREATION	AND STATE	
	HEALTH CARE	AUTHORITIES	SII/API
	FOOD SUPPLY		
	CEMETERIES		

Fig. 1 - Urban aspects for surveying

SII - Satellite Images Interpretation
API - Aerial Photography Interpretation

TABLE 1
MATERIAL OF STUDY

	MSS	TM	BASE MAP	DISTANCES
DATE	24/9/73	17/6/86	1981	-
SCENE ELEMENT SIZE	79 mm	30 mm	-	-
PIXEL SIZE	100 µm	50 µm	-	-
SCALE	1:800.000	1:600.000	1:250.000	-
ENLARGEMENT	1:100.000	1:100.000	1:100.000	
Measurements: CAXIAS/ FARROUPILHA:	2,1 cm	3,0 cm	7,0 cm	17.5 km
FARROUPILHA/ BENTO:	2,2 cm	2,9 cm	7,0 cm	17,5 km
FARROUPILHA/ GARIBALDI:	2,2 cm	3,0 cm	7,3 cm	18,25 km
CAXIAS/BENTO:	4,0 cm	5,4 cm	13,0 cm	32,5 km

TABLE 2
URBAN AREAS GROWTH

URBAN AREAS	AREA IN HECTARES 1 HA = 100 X 100 m MSS/73	TM/86	GROWTH % 73/86
BENTO GONÇALVES	770	2130	64
GARIBALDI	370	750	51
FARROUPILHA	500	1340	63
CAXIAS DO SUL	2200	4630	53
TOTAL	3840	8850	57

Source: Satellite printed images interpretation, scale 1:100.000, processed by USEMAP IV software package, ITC, 1988.

TABLE 3
BENTO GONÇALVES URBAN AREA
COMPARISON

AREA IN HECTARES
1 HA = 100 X 100 m

	API/86	TM/86	DIFFERENCE
URBAN AREA	1610	2130	520

Source: Satellite printed images and aerial photographs interpretation, scales 1:100.000 and 1:8.000, processed by USEMAP IV software package, ITC, 1988.

TABLE 4
CITY LOCATION ACCORDING THREE SLOPES CLASSES

	AREA IN HECTARES 1 HA = 100 X 100 m
CITY IN PLATEAU	570
CITY IN STEEP SLOPES	660
CITY IN MEDIUN SLOPES	900
TOTAL	2130

Source: TM/1986 satellite printed images interpretation,scale 1:100.000, processed by USEMAP IV software package, ITC, 1988.

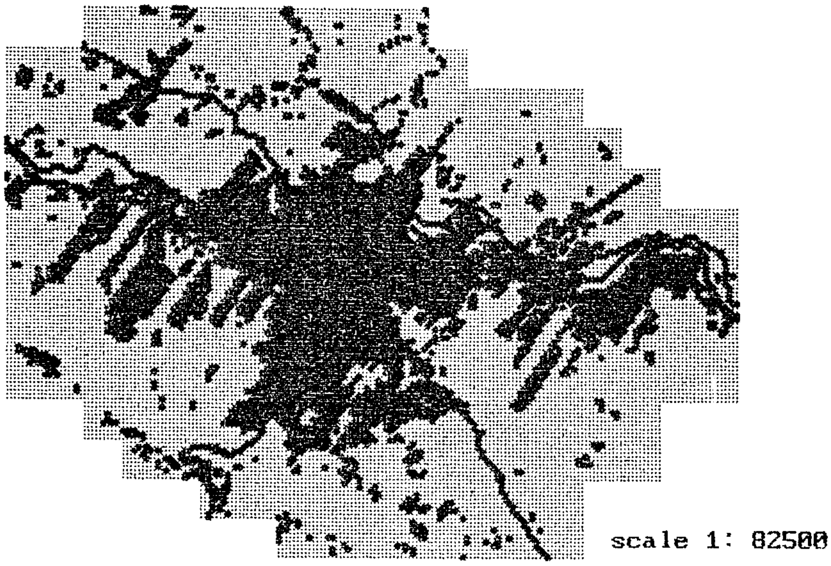

Fig. 5 - Area delineated as "urban area" in the interpretation of black & white aerial photographs of Bento Gonçalves scale 1:8.000.

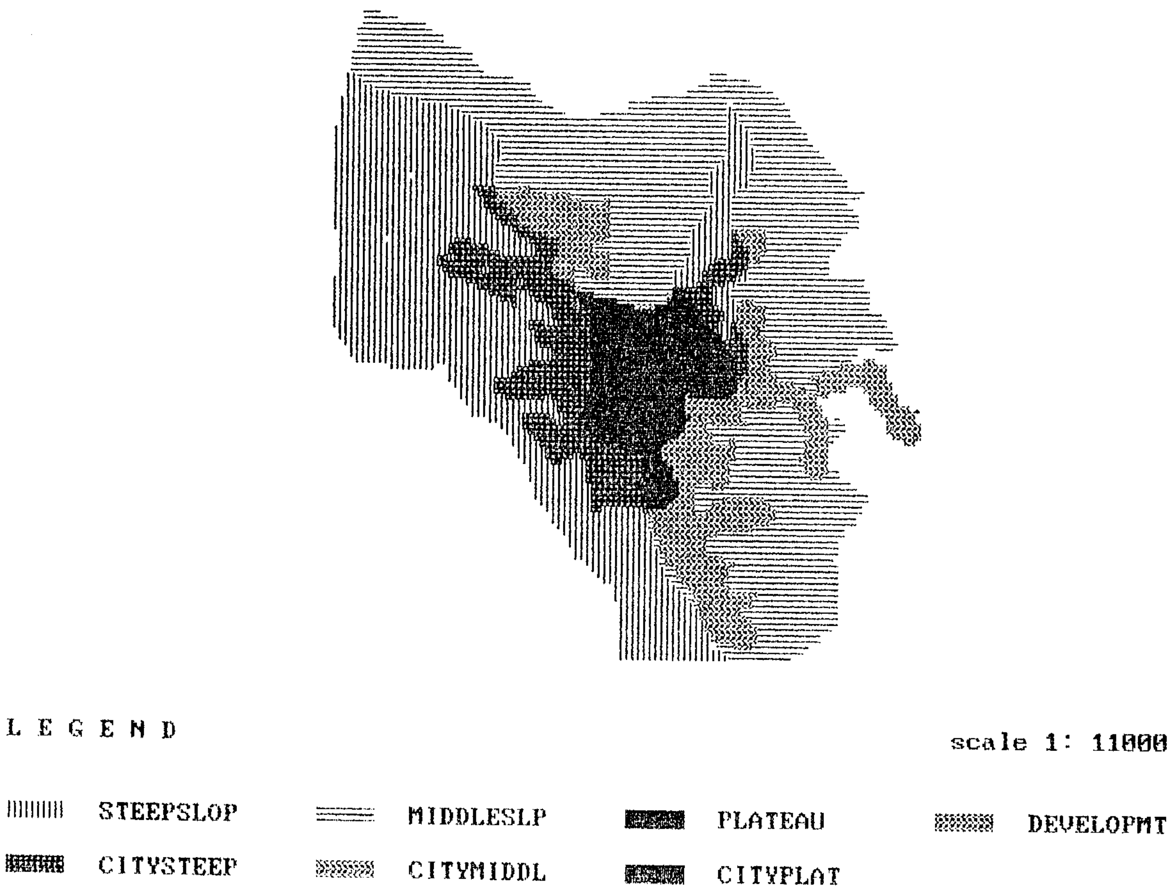

Fig. 6 - Comparison between the area delineated as "urban area" and the areas delineated according to three slopes classes: steep, mediun and central plateau.

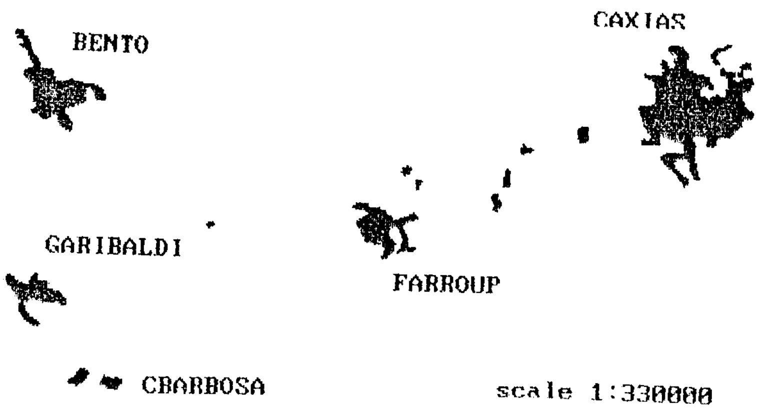

Fig. 2 - Areas delineated as "urban area" in the interpretation of MSS/LANDSAT/1973-false-colour-composites scale 1:100.000.

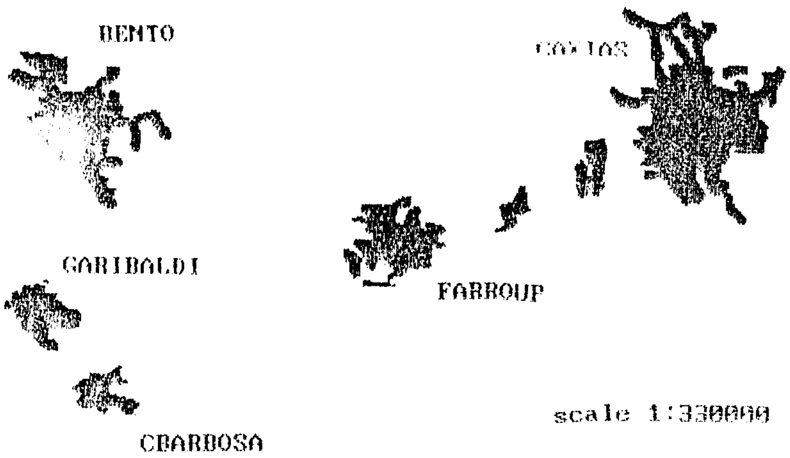

Fig. 3 - Areas delineated as "urban areas" in the interpretation of TM/LANDSAT/1986-false-colour-composites scale 1:100.000.

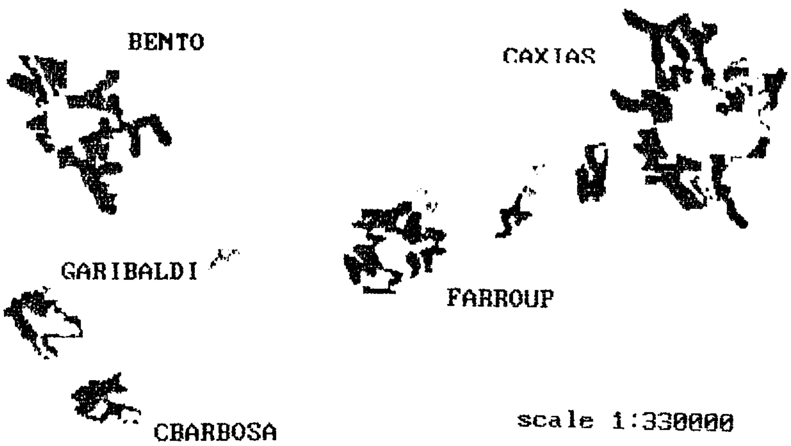

Fig. 4 - Comparison between the MSS and TM interpretations showing the growth of the cities in the period 1973-1986.