An Alternative to Updating Topographic Maps Using SPOT Images

Maria Isabel Castreghini de Freitas
UNESP – Universidade Estadual Paulista, Brasil
Instituto de Geociências e Ciências Exatas
Departamento de Planejamento Territorial e Geoprocessamento
Miviadan@rc.unesp.br

KEY WORDS: topographic map, SPOT image, cartographic updating

ABSTRACT

Brazil has serious problems in systematic mapping and cartographic updating. Only 13% of the country is mapped in scale 1:50,000 and most of these maps are from approximately 30 years ago. Usually, professionals such as planners, engineers and geographers need updated documents to develop their work in regional scale. Sometimes they need to elaborate maps by themselves, using basic knowledge in Cartography and Remote Sensing applied through alternative methodologies. The main aim of this paper is to updating a 1:50,000 topographic map using SPOT-HRV panchromatic and multispectral images through a low cost methodology. The area of study corresponds to the topographic map from the region of Rio Claro, State of São Paulo, Brazil, produced by IBGE (Brazilian Institute of Geography and Statistics) in the 1:50,000 scale. The software utilized were AutoCAD R.12 and Idrisi for Windows. The methodology includes application of Digital Image Enhancement through HSI transformation in the SPOT multispectral and panchromatic images as well as techniques of visual interpretation through the GIS Idrisi. The SPOT images were registered using control points selected from topographic maps in 10,000 scale, from IGC (Geographic and Cartographic Institute) from the State of São Paulo. A preliminary verification of the updated information content was made using aerial photographs in scale 1:25,000. After that, seven fieldwork's were performed to solve doubts of the final interpretation. The comparison of the informative content performed showed the image potential to updating tasks, especially concerning to roads, watercourses and railways. Some difficulties appeared in the interpretation of the energy transmission lines, mainly due to the discontinuities in the visualization of the high-tension protection zone. The analysis of the image registration precision presented approximately the RMS equal to 34.96 m for the studied image composition, compatible with the research expectancy. The interpretation of aerial photographs and field verifying solved doubts in the updating process and had an important contribution to the final updated map. The results concerning information content highlight this alternative to updating topographic maps with low cost through an alternative methodology.

1. INTRODUCTION

Maps are fast information sources when we want to know, to study and to develop projects in any region. Users, when consulting a map, expect information to be found. Sometimes, information can not appear due to scale or to the not updating of the map. Keates (1982) affirms "all maps are selective". In this way, it is necessary to adapt the scale and content to the desired objective of the map.

In Brazil, most of the available maps to users are in an unsatisfactory scale and not updated. Nowadays, we have developed different methodologies to updating maps, using especially orbital images from Landsat-TM and SPOT-HRV. It is important to consider and evaluate questions such as area dimension, methodology quickness and easily, updating quality and change detection capacity through time. The detection capacity is associated to the informative content of the images used, whether they are aerial photographs or orbital images.

This paper presents the continuation of results of the research done by Viadana (1995) where tests were performed with Landsat-TM and SPOT-P (panchromatic), showing the potential of orbital images to updating 1:50,000 topographic maps.

1.1. Objectives and Justification

The main aim of this paper is to updating a 1:50,000 topographic map using SPOT-HRV panchromatic and multispectral images.

The specific aims are:

- Applying enhancement techniques to orbital images highlighting features of interest; choosing the best final image composition to updating 1:50,000 map;
- Updating linear features as roads, railways, energy transmission lines and watercourses. Delimitation of urban areas are updated too;
- Using Geographic Information System IDRISI FOR WINDOWS 2.0 and evaluating its potential to updating maps;
- Using scanner to have the original map in digital environment and using software TRACER to obtain vectorial features of original features of interest;
- Evaluating results in terms of informative content and geometric precision of the final adopted composition to updating.

Applying this updating methodology in a 1:50,000 topographic map is justified by the critical situation of systematic mapping in Brazil. The last date survey (Brasil, 1991) accounted for 13.1% of existing maps in 1:50,000 scale, mainly in the Southeast and in the South, regions with more development. It means that 86.9% of 1:50,000 maps are still to be executed, corresponding to 11,928 of foreseen maps. Besides that, these existent maps have not been updated for 30 years.

1.2. Area of Study

The area of study corresponds to an area covered by a topographic map from *Instituto Brasileiro de Geografia e Estatística* (IBGE), the Brazilian Institute of Geography and Statistics, SF-23-M-I-4, called Rio Claro, scale 1:50,000, edited in 1969, in Universal Transverse of Mercator (UTM) Projection and based on aerial photographs from 1965. The area of study corresponds to approximately 25.5km x 27.5km, with latitudes 22º15´S and 22º30´S and longitudes 47º45´W and 47º30´W, in the surroundings of Rio Claro, State of São Paulo, Brazil.

2. Updating Methodologies using Orbital images

The updating methodologies include both conventional and digital cartographic processes using photographs, orthophotographs and orbital images.

The cartographic updating includes preparing source data (photographs, orthophotographs, orbital images); detecting changes; including new features in the original map and/or removing inexistent features; field verification and final art.

In Brazil, in order to produce topographic maps, the standard of planimetric precision for systematic maps and photomaps is 0.5mm in map scale. The precision for elevation data is half-contour interval.

Difficulties in change detection and quality control to preserve geodetic base in field and low financial investments in cartography are limiting factors to updating existent maps in Brazil.

The SPOT satellite began operations in 1986, with two identical sensors called HRV (*Haute Resolution Visible*) registering multispectral images SPOT-XS with Band 1 (λ=0.50-0.59µm), Band 2 (λ=0.61-0.68µm), Band 3 (λ=0.79-0.89µm) and resolution of 20m. The panchromatic images SPOT-P with Band P (λ=0.50-0.59µm) and resolution of 10m. These images have potential to produce and update maps in scale 1:100.000 until 1:50,000.

In cartographic updating using orbital images it is important to evaluate the geometric precision and informative content of the utilized remote sensing products.

Some papers were fundamental to develop this research. Among them is Meneguette (1987) that showed the mapping and revision work with Landsat TM images and orbital images and orbital photographs from Metric Camera in scales 1:50,000, 1:100,000 and 1:200,000 from France, Libya and Brazil. Furthermore, image maps were generated for map revision. As a conclusion, the author points out that most of the maps are in the standards of cartographic precision. The Metric Camera images provide detection of a large number of features but a significant portion of this information was not clear or was lost. The same occurred with TM images from Brazil, presenting inadequate results to mapping and revision in the 1:50,000 and the 1:100.000 scales. Therefore, although the cartographic and geometric precision were in the standard, the informative content limits the use of these orbital images and photographs for mapping and revision in middle scales.

The paper by Meneguette (1988) presents software called digital monocomparator plotter, developed for compilation and revision of digital maps resulting from satellite images and orbital photographs. This study highlights the importance of the information content in cartographic applications using orbital images.

Sanchez (1987) used HSI (Hue, Saturation and Intensity) transformation working with Landsat-TM and SPOT-P. In that experience, the chosen image compositions (TM-RGB) were TM-432 and TM-543. The author applied HSI transformation and, in the HSI space substituted component I (Intensity) by SPOT-P image, with has a better resolution. Through an inverse transformation he obtained a color composition corresponding to a hybrid image mixing Landsat-TM with SPOT-P. The selected image for final mapping was the color composition utilizing TM-432 and SPOT-P.

Viadana (1995) produced a multi-resolution composite image for mapping at 1:50,000 scale using Landsat TM and SPOT-P. The HSI transformation was used with the two kinds of products, in different image compositions and the TM-432 was chosen to be tested. The SPOT-P was used to replace the component intensity (I) in order to improve the geometric resolution of the resulting image.

3. Methodology

3.1. Data Acquisition

In this paper a HRV image, from SPOT satellite, level 1B in panchromatic mode, with 10 m spatial resolution and 3 bands in multispectral mode, with 20 m resolution from August 21, 1995 (K714 - J394) was used. In addition to that, topographic maps from IBGE in 1:50,000 scale, from 1969 and from Intituto Geográfico e Cartográfico (IGC), the Geographic and Cartographic Institute in 1:10,000, from 1978, both in the UTM projection, were utilized. The original data from IBGE topographic map was scanned using a scanner that registered the map in TIFF format. The Tracer for AutoCAD v.2.01 generated features in digital vector format. In order to present the original map in the vector format and for the final editing of the updated map, AutoCAD R.12 was used. The features were distributed in layers corresponding to existent information such as urban areas, paved roads, dirt roads with continuous traffic and with periodical traffic, trails, railways, energy transmission lines, watercourses and contour lines.

The map was edited and exported to IDRISI using the DXF format. Limitations in software IDRISI do not permit to recognize layer classification of AutoCAD, forcing the production of one DXF file for each original layer.

3.2. Image Registration

Before the enhancement of orbital images, control points were selected for SPOT-P and SPOT-XS images for the geometric registration. A total of 20 control points was detected in each image and in the original maps from IGC, scale 1:10,000, and a 1^{st} degree polynomial model was chosen to make the image registration. Due to the two sets of data presenting different spatial resolutions, the SPOT-XS data were resampled by using a double expansion factor, resulting in a spatial resolution of 10 m.

3.3. Image Enhancement

Techniques for the enhancement of orbital images are made to improve the quality of images to visual interpretation of the interest features. Then, through a rigorous selection, using interpretation elements, one image composition was chosen: the merged composition of the SPOT-P and SPOT-XS, using the HSI transformation as refereed in Sanchez (1987), Chavez (1991) and Viadana (1995).
The space color in HSI is defined by hue, saturation and intensity attributes. Before doing the transformation, the histogram equalization by manual method was applied to the images involved in the research, searching for a higher balance among the associated colors in RGB (red, green and blue) Color Space. The process involved the transformation of each chosen SPOT-XS band from the RGB Space into HSI color space and the replacement of the intensity component by SPOT-P image. Then, using simple linear stretch, was obtained a new RGB merged image through the inverse transformation of H, S and I (substituted by SPOT-P). This procedure intended to combine the higher spatial resolution of the SPOT-P with the best spectral resolution from the SPOT XS-321 composition. Some control features were analyzed concerning to the following elements of interpretation: shape, pattern, color, texture and association. Through the visual analysis of control features, the best image to attend those updating objectives resulted from the XS-321 composition plus SPOT-P image, despite the tests performed individually with SPOT-P and SPOT-XS individually.

3.4. Screen Digitizing and Editing

The screen digitizing was made with the specific IDRISI's mode. The new linear features were registered by observing the image in the background covered by the original map. Non detected features were kept for future ground verification. Files with the updated maps were generated in vector format, transformed in DXF and exported to AutoCAD R.12. The editing in AutoCAD involved basically the closing of polygons and features intersections. Then, the features were distributed in layers: new paved roads, new dirt roads, new railways, new energy transmission lines, new urban area, repeated features and undetected old features.

3.5. Preliminary Verification and Field Work

A preliminary verification of updated features was scheduled to reduce the fieldwork, using available aerial photographs in the 1:25.000 scale, from 1995. The amplified copies of the updated map composed a mosaic at the 1:25.000 approached scale, printed in polyester.
The preliminary updated map was named “Updating Draft”.
Features present in aerial photographs and not registered through image interpretation were included in the updating draft for future verification in the orbital image. In the case of possible identification in the orbital image, the features were included in the new map.
After this step, the fieldwork was done to solve problems unsolved in the preliminary verification. Seven sections of fieldwork were done, of approximately 12 hours each, in order to verify features with different interpretations, and those features not registered in the updating draft. The fieldwork offered important information about the classification of dirt roads (with permanent traffic, periodic traffic and trails) and about the energy transmission lines (high tension and low tension). The preliminary verification made easy the fieldwork and resulted in a fast and less expensive updated map. If photographs are not available for the study areas, more time is needed for fieldwork.

3.6. Final Interpretation

The aim of this step is to complement the first interpretation with the field reality. A new map was made using the product of image and photo interpretation plus the field reality registered in the updating draft. Analyzing the content of the map, all features had a superabundance of information. It was opted for the inclusion of changes detected in fieldwork. All corrections were made in AutoCAD and after exported to IDRISI. In IDRISI images (raster format) for length and area calculation were created. After that, a new transformation for vector format was made to final editing of the updated map in AutoCAD.

4. Results

The results of this research are an updated topographic map of Rio Claro, with additional field information and tables concerning information content.

4.1. Updated Topographic Map

An updated map resulting from merged image, from HIS transformation was produced. The figure 1 presents the final updated topographic map from IBGE, 1:50,000 scale, called Rio Claro. The elevation features (contour lines and elevation points), from the original map, were omitted in this figure to make possible the visualization of the interest features.

4.2. Image Registration Precision Results

In order to evaluate the precision of image registration by RMS analysis in generated product, 15 verification points were used. The ground co-ordinates were obtained from IGC maps, 1:10,000 scale and the results are shown in table 1.

HSI IMAGE COMPOSITION	**Geo-referring Precision Results (m)**
RMS_E	22.48
RMS. $_N$	26.78
RMS. $_{E,N}$	**34.96**

Table 1: Geo- referencing precision results

Analyzing the results and having as a parameter the planimetric precision of 25 m for mapping production in the 1:50,000 scale in Brazil, it is possible to verify that the RMS equal to 34.96m is acceptable to the updating task developed in this research. The available software and data are limiting factors to increase the precision in this updating methodology.

4.3. Information Content

The measuring of the information content was made through analysis tools from IDRISI to length in meters (m) and areas in square meters (m²).

The quantitative evaluation of original and updated features is presented in Table 2.

Features Studied	Original Topographic Map		Updated Map	
	Length (m)	Area (m²)	Length (m)	Area (m²)
Paved Roads	406,300		1,284,071	
Dirt Roads with permanent traffic or trails	1,500,100		1,099,874	
Dirt Roads with periodic traffic or trails	4,475,800		5,606,567	
Railways	793,200		609,734	
Energy Transmission Lines	1,181,800		1,549,409	
Watercourses	5,441,400		8,605,260	
Urban Areas		10,315,629		43,213,551
Ponds and Dams		1,581,293		2,295,254
TOTAL	**13,798,600**	**11,896,922**	**18,754,915**	**45,508,805**

Table 2: Length and area of features from original map and updated map.

Table 2 shows that the resulting map added a large quantity of information to the original map. The great increase of paved roads is due to the change of category of dirt roads with permanent traffic to paved roads in the last 30 years. This justifies the decrease of dirt roads with permanent traffic in the updated map. The energy transmission lines increased approximately 300km, besides difficulties to identify this category in the interpretation. The watercourses increased in approximately 3,000km. Finally, the urban area had a total increase of 33km², showing the high concentration of population in cities, a common phenomenon observed in the last 30 years.

4.4. Analysis of Results

The obtained results are shown in table 3 highlighting old features detected and preserved, new features resulting of image interpretation as well as old features with a significant change when compared with the original map. In reality, the column field verification in table 3 corresponds to the contribution of aerial photograph interpretation followed by fieldwork for the final updating.

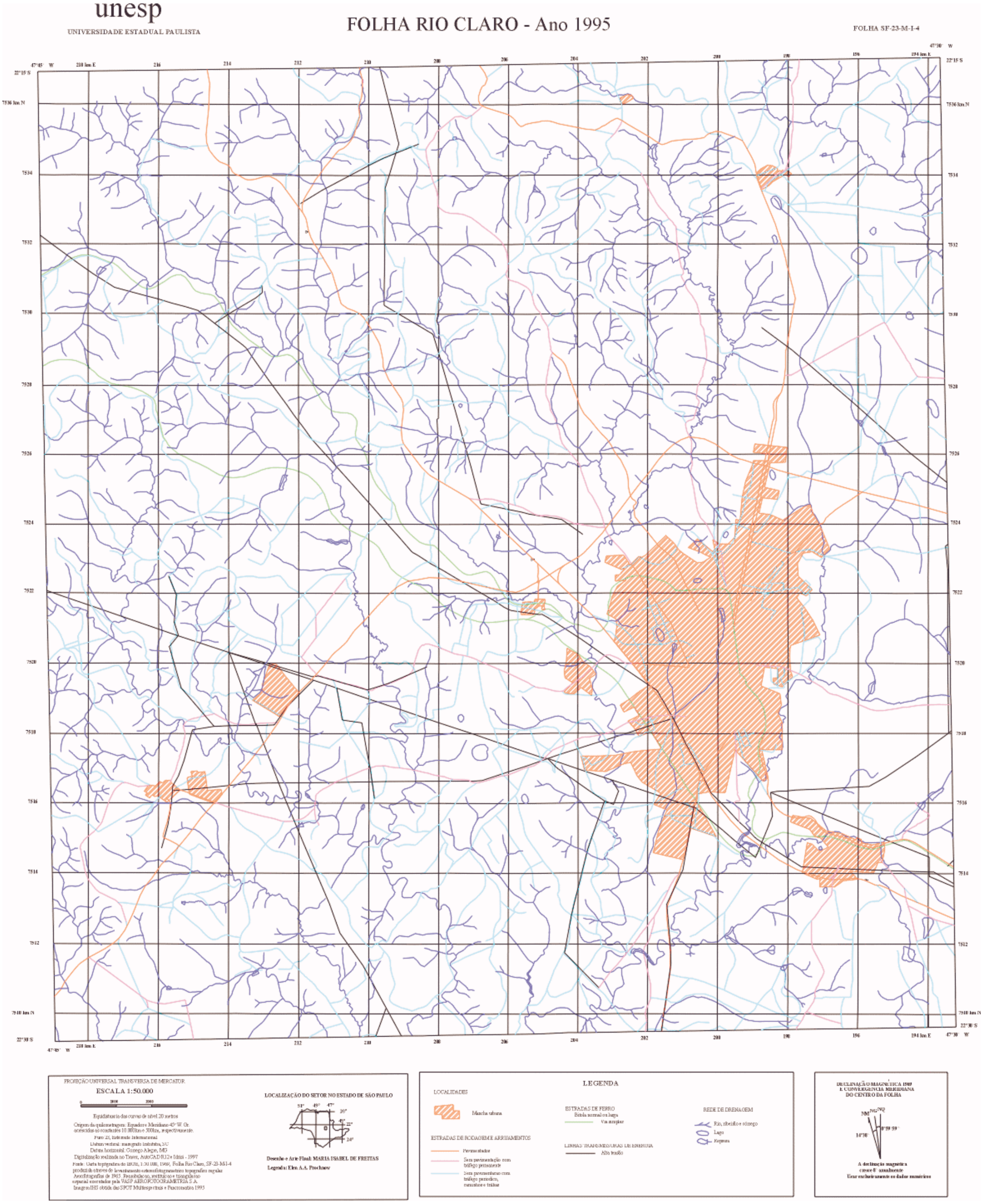

Figure 1: Updated topographic map 1:50,000 from Region of Rio Claro (without the elevation features).

IMAGE HSI	Old Features	New Features	Field Verification	Total
Paved Roads (m)	406,300	841,283	36,488	1,284,071
Dirt Roads with Permanent Traffic (m)	939,880	72,752	87,242	1,099,874
Dirt Roads with Periodic Traffic and Trays (m)	3,861,868	1,575,357	169,342	5,606,567
Railways (m)	362,042	247,692	-	609,734
Energy Transmission Lines (m)	916,326	633,083	-	1,549,409
Watercourses (m)	5,155,740	3,386,949	62,571	8,605,260
Pounds and Dams (m^2)	1,581,293	713,961	-	2,295,254

Table 3: Image and Field Verification contribution to updating.

Analyzing table 3, it is possible to observe the importance of field verification (photointerpretation and fieldwork) in updating of roads in general, highlighting dirt roads and trays, followed by paved roads.
About railways it is necessary to observe that this kind of transport system is in an abandon process in the last decades in Brazil. It was possible to confirm some portion of railways transformed in dirt roads and trails. The fieldwork confirmed the image interpretation.
In the updating of energy transmission lines (especially high tension) a non-continuity of these features in the orbital image was detected, mainly in pasture areas. Despite the field confirmation, it was impossible to see the complete features in the orbital image, reason why information from field verification was not included in the respective column of table 3.
The results presented for watercourses showed the potential of the SPOT merged image for detecting details of the source areas of the same.
It was not possible to make field verification in urban areas. The urban expansion, represented mainly by the city surroundings, was registered.

5. Conclusions

The research results point to the potential of orbital images as a low cost alternative methodology to the updating of topographic maps at the 1:50,000 scale, according to the needs of regional planning users.
The analysis of the image registration precision presented approximately the RMS equal to 34.96 m for the studied image composition, compatible with the research expectancy. This paper is centered in producing a kind of map classified into the category of derived source maps, with precision compatible to middle scale base maps for thematic applying.
The comparison of the informative content performed showed the image potential to updating tasks.
The categories, roads paved and dirt roads, gave the best contribution to the updating process. The existent railways were completely identified. The features related to watercourses present precise location and easy updating, pointing to a significant increase of the information content in this category. The worse performance was the updating of energy transmission lines, due to the protection zone and the kind of land use in the neighborhood. The interpretation of aerial photographs and field verifying solved doubts in the updating process and had an important contribution to the final updated map.

Acknowledgement
The author wishes to thank the financial support given by the Foundation for Supporting the Research of the State of São Paulo, Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP).

Bibliography

Brasil, 1991. Ministério da Economia, Fazenda e Planejamento. Fundação Instituto Brasileiro de Geografia e Estatística. Mapeamento Geral do Brasil. s.l. Escalas diversas. 9 mapas.
Chavez, P.S.; Bowell, J.A., 1988. Comparison of the spectral information content of Landsat Thematic Mapper and SPOT for three different sites in the Phoenix, Arizona region. Photogrammetric Engineering and Remote Sensing, 54(12), p. 1699-1708.
Keates, J.S., 1982. Understanding Maps. New York, John Wiley & Sons Inc. 139p.
Meneguette, A.A.C., 1987. Cartographic accuracy and information content of space imagery for digital map compilation and map revision. London, Ph.D. Thesis – University College of London. 464p.
Meneguette, A.A.C., 1988. Exatidão cartográfica e conteúdo informativo de imagens de satélite para compilação e revisão de mapas digitais. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, V. Anais. São José dos Campos, INPE, p. 232-235.

Sanchez, R.D., 1987. Image mapping of the Viedma area, Argentina at 1:50,000-scale using merged LANDSAT TM and SPOT P data. Revista Cartográfica. v.51/52, p.123-131.
Viadana, M.I.C.F., 1995. Atualização de Cartas Topográficas Utilizando Imagens Orbitais - Metodologia Alternativa para Microcomputadores. São Paulo. 135p. Tese de Doutorado. Curso de Pós-Graduação em Engenharia de Transportes, Escola Politécnica da Universidade de São Paulo.