GEOBIA AND WORLDVIEW-II IMAGES FOR THE IDENTIFICATION OF MANGROVE FRAGMENTS AT THE NORTH OF SÃO LUÍS CITY – MA, BRAZIL

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ABSTRACT:

As a contribution for the maintenance of coastal ecosystems due to its biodiversity and importance, the objective of this paper is to identify the main mangrove fragments at the northern section of São Luis city, considering the object-based approach. This study is based on WorldView-2 satellite images, using the recently developed InterIMAGE software. Initially the multispectral channels were fused to the panchromatic channel, followed by image ortho-rectification, using GCPs (Ground Control Points), collected during field survey. An exploratory analysis and the evaluation of the most adequate GEOBIA attributes considered parameters such as: form, texture and context in order to elaborate a knowledge model applied at the InterIMAGE software. Afterwards segmentation was done followed by image classification. In the sequence, spatial analysis techniques were used, allowing the improvement of visualization from mangrove fragments within the area under study. The results demonstrate the importance of efficient urban planning in order to mitigate negative impacts at certain urban districts and also to direct urban expansion to avoid the destruction of remaining mangrove fragments.

1. INTRODUCTION

The constant monitoring and management of vegetation fragments which occupy the coastal zone of Maranhão State, are important for the protection of fauna and flora from this area. At São Luis city, localized at the coast of this State, a strong population increment occurred since the 60s, due to commercial and industrial activities, decreasing and degrading the mangrove fragments.

With the availability of high resolution data from WorldView-2 satellite, launched in October 2009, new possibilites were opened for the study of mangroves in urban areas, because this is the first orbital sensor with 0.46m resolution at the panchromatic band and 1.84m at the multispectral bands.

In order to analyze these huge datasets, new methodologies and concepts were developed. OBIA (Object-based Image Analysis) is a paradigm indicated for the classification of land use/land cover in urban areas, using these very high resolution images (BLASCHKE e KUX, 2007). InterIMAGE, a free and open code image interpretation and knowledge-based system was jointly developed by INPE and the Pontificial Catholic University of Rio de Janeiro (PUC-Rio), Dept. of Electric Engineering (COSTA et al., 2010).

The objective of this work is to identify the main mangrove fragments at the northern districts of São Luís city, considering the OBIA paradigm, using WorldView-2 images and working with the InterIMAGE software.

After the identification and spatial distribution of these fragments, these information were crossed with census data from 2010 (the same year of the WorldView-2 data take) for the spatial analysis of variables, and main impacts over these areas.

1.1 GEOBIA – Geographic Object-based Image Analysis

For the analysis of high resolution satellite images, the traditional pixel by pixel classification approach is quite limited because these data present a high level of heterogeneity as well as an internal class variation within the same scene. BLASCHKE (2010) presented the evolution of OBIA, presenting case studies in different applications. At this paradigm, the classification considers information extracted from objects, topological (neighborhood, context) and geometrical (form, size) data.

Other attributes such as: size, texture, pattern and context are helpful for the classification when the spectral attributes are not sufficient and the knowledge from the specialist is inserted to improve this task. BENZ et al. (2004) report that this uncertainty must be modelled, which will help on the evaluation of the classification. HAY & CASTILLA (2008) define GEOBIA (Geographic Object Based Image Analysis) as a sub-discipline of Geoinformation Science, dedicated to the development of automated mathods to partition remote sensing images in meaningful objects.

1.2 Image fusion

The fusion of panchromatic with multispectral images of WorldView-2 scenes was done using the Principal Components methods, resulting in an image with 0.50 m spatial resolution.

1.3 Orthorectification

The orthorectification was made using the 3D rational polynomial method (TOUTIN, 2004), from software package PCI Geomatics v10.3.1, considering 55 GCPs for the entire area under study. The GCPs used for the geometric rectification were obtained during a field campaign in August 2011.

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1.4 Semantic network

In order to compose the semantic network, the following land cover classes were defined for the test sites, based on the visual analysis of WorldView-2 images and on the previous knowledge of the area by the interpreter.

The mangrove areas were discriminated in Arboreal vegetation (mangroves) and marsh area (*Apicum*, low vegetation type). Other classes: Bare soil, Roofs (Ceramic, Metal and Asbestos), Asphalt pavement, Tidal flat and Tidal channel.

1.5 InterIMAGE

InterIMAGE is a knowledge-based free software for image interpretation. It was developed in the frame of a cooperation project between INPE, the Brazilian National Institute for Space Research, the Laboratory for Computer Vision of the Catholic University of Rio de Janeiro (PUC-RJ), and the Leibniz University of Hannover (Germany). According to COSTA (2009 and 2010), its knowledge structure, design and control mechanisms were inherited from the German system GeoAIDA (BÜCKNER et al., 2001), which consists of a further development from AIDA (Automatic Image Data Analyzer).

According to RIBEIRO (2010) the most important characteristics of InterIMAGE are its flexibility for the interpretation of multi-sensor images and the reduction of computer processing time and THE load for the image analysis.

The most recent version of InterIMAGE can be downloaded at link http://www.lvc.ele.puc-rio.br/projects/interimage/.Among other operators for object extraction it contains: a segmenter from Baatz, the Checkerboard, a classifier by decision trees, an importer for vector files, topologic attributes which can be used at the decision rules of Top-Down and Bottom-Up operators (COSTA et al., 2010;).

1.6 Data Mining and GEODMA

Data Mining consists on the application of computer algorithms over a data base aiming to abstract new and useful knowledge. WITTEN & FRANK (2005) inform that these algorithms, according to certain paradigms, are based on techniques aiming to explore data to produce knowledge models which express patterns of data characteristics which can be extrapolated for the classification. CARVALHO (2011) presented the first land cover/land use mapof urban areas in Brazil, using Data Mining techniques.

GeoDMA executes all processing phases needed to manipulate remote sensing data, including segmentation, extraction and selection of attributes, training, classification and exploratory data analysis.
According to KORTING et al., (2009) the use of data mining tools can increase the analysis potential of remote sensing data when they are employed in urban areas, because of the variety of targets, which are difficult to discriminate at these environments, considering the variety of targets which require more accurate techniques for the information extraction.

1.7 Spatial analysis of geographic data

The spatial analysis helps to process data to be used allowing also, through an exploratory analysis, to understand the attributes and variables which would explain certain processes. Crossing information obtained from satellite images with data from public management institutions, as well as data of environmental fragility obtained by geo-spatial inferences, can indicate the present state of environments under stress, such as certain mangrove covered areas.

2. AREA UNDER STUDY

The area under study is part of the Maranhão Island, NE Brazil, encompassing an area of 831.7 Km².
To map mangrove forests, a test site was chosen which includes a mixture of different growth stages of this vegetation type, including those sections suffering strong human pressure as well as those recovering from earlier impacts, which are representative for the present situation all over this island. The test site is shown on Figure 1.

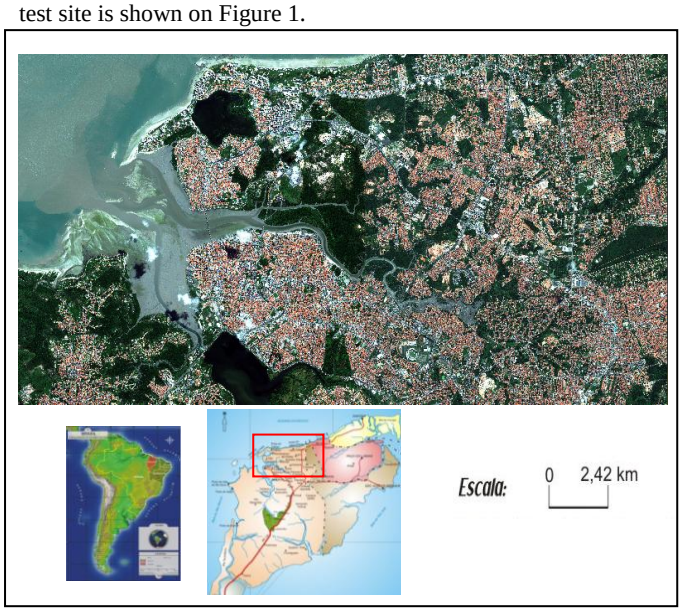
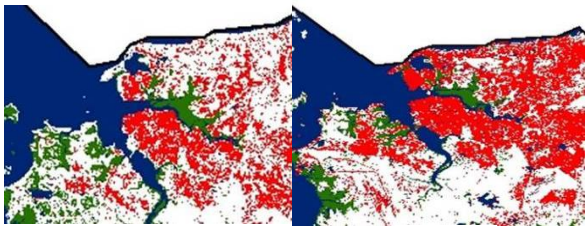


Figure 1 – Localization of test site
Source: Adapted from WorldView-2 image dated July 10th 2010. (DIGITALGLOBE, 2010).

At the northern section of São Luis municipality there are fragile geologic structures of Quaternary age, which eases the landscape change by relief modeling agents of climatic, hydrologic and oceanographic origin. A detailed description of this area is found in SOUZA & FEITOSA (2009) and GERCO (1998).

Associated to this fragile underground structures, the mangroves are located mainly at the margins of bays, inlets, river mouths, lagoons and coastal indentions. Such vegetation systems are functionally complex, highly resilient, resistant and stable, occurring exclusively in tropical areas. They are characterized by a characteristic vegetation and sediments and are very important from an environmental and social-economic point of view (MOCHEL, 2006 p. 237).

At figure 2, which shows a TM-Landsat classification of the urban area (in red) and the mangrove classification (in green) at two different dates (2000 and 2010) one perceives clearly the reduction of mangroves in the time interval of 10 years and a strong increment of the urban area .



2000 2010

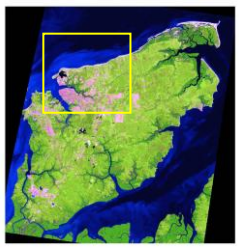


Figure 2: Increase of the São Luis urban area at the cost of mangroves, at the northern section of the island.

For the elaboration of a semantic net to map mangrove fragments, a representative test site was chosen with the characteristic height and density of mangrove forests which contains also other objects associated to it, such as tidal channels and blockhouse occupation, as shown on Figure 3, where the improved spatial resolution allows to identify in detail the heterogeneity of the scene under study.

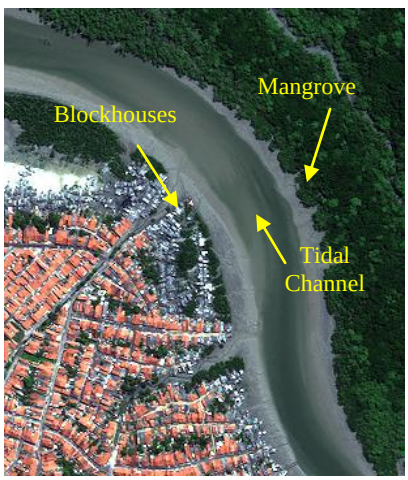


Figure 3 – Test site.
Source: adapted from WorldView-II image, dated July 10th 2010. (DIGITALGLOBE, 2010).

3. METHODOLOGY

The main methodological steps are presented in the flow diagram at Figure 4:

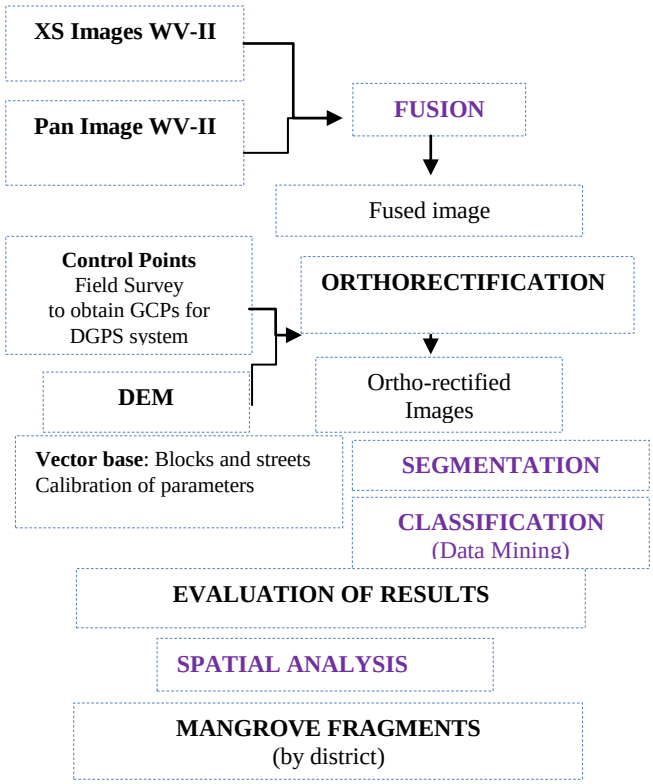


Figure 4 – Methodological steps

Materials used:

1) Scenes from *WorldView-II* sensor obtained in June 10th 2010, with off-nadir angle 16º and 11 bits radiometric resolution, delivered by DIGITALGLOBE.

2) Vector files of blocks in the databank of São Luis, from the city planning agency.

3) GCPs collected during Field survey in August 2011 with TOPCON Hiper L GPS geodetic equipment.

4) Contour lines in vector format, 1 m equidistance of contours, for the São Luis region.

5) Census data from 2010 encompassing the area under study, delivered by IBGE (Brazilian Institute for Geography and Statiscs).

The following software was used for image processing: ENVI 4.7 (ITT, 2009), used for fusion and cutting of both test sites: PCI Geomatics V10.3.1 (PCI Geomatics, 2010) to work with the Digital Elevation Model and control points, followed by WorldView-2 image orthorectification, InterIMAGE v1.27 (InterIMAGE 2010) and GeoDMA for the exploratory analysis of image attributes and land cover classification.

The SPRING 5.1.7 software, developed at INPE, was used to generate vulnerability maps of mangrove areas of the northern section from the Maranhão Island and for the spatial analysis.

4. RESULTS

Based on the attributes chosen, a thematic land cover map was generated from the classification of WorldView-2 data, using InterIMAGE v1.27 and data mining of GeoDMA. This software allowed a supervised analysis of the different attributes and to define the best ones and the thresholds used for the classification.

During the implementation of the hierarchical network, the classification process implemented at InterIMAGE was considered, using the Top-Down and Bottom-Up approach. The option was a network with few levels and many leaf nodes which allow lower computer costs (RIBEIRO, 2010).

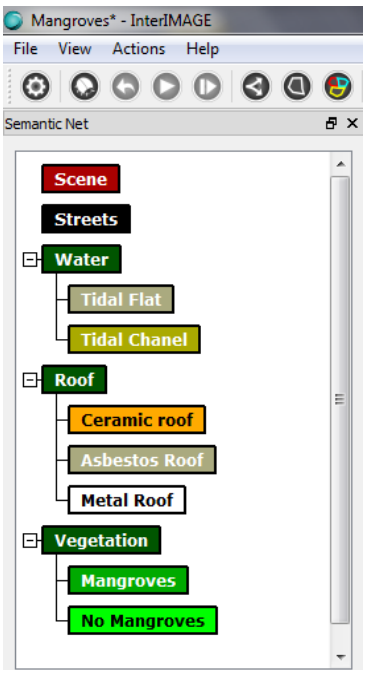


Figure 5: Semantic network elaborated at InterIMAGE.

After structuring the semantic network (Figure 5), the segmentation of the scene was performed (Figure 6), where the leaf nodes perform a logic selection and transmit to the parent-node a reduced number of hypotheses, for later object classification at the Bottom-Up phase. The conflicts are solved attributing membership values to each class, prioritizing those attributes which define classes with less omission and commission errors.

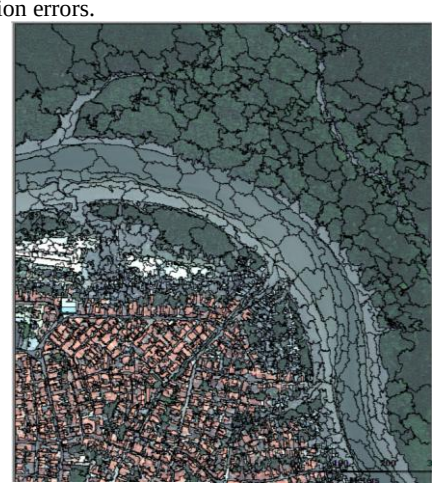


Figure 6: Segmented image.

After the evaluation of the analysis most robust attributes at the exploratory analysis, including the texture attributes implemented at InterIMAGE vl. 27, the scene classification was performed (Figure 7). In comparison to other classifications the results were more improved due to the availability of WorldView-2 new bands Yellow and Red Edge, eliminating frequent confusions such e.g. among Ceramic Roofs and Bare soil.

The mangrove fragments were well classified, according to figure 8, and the semantic net can be expanded for the surrounding area of the entire area under study.

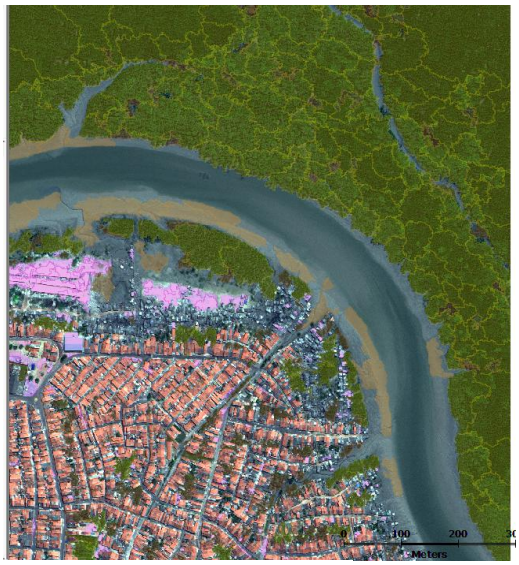


Figure 7: Final classification of the scene.

The classification obtained by InterIMAGE was exported on the Shapefile format, and used for the evaluation of the main city districts and, after a field control, the following map with the representation of fragments was established:

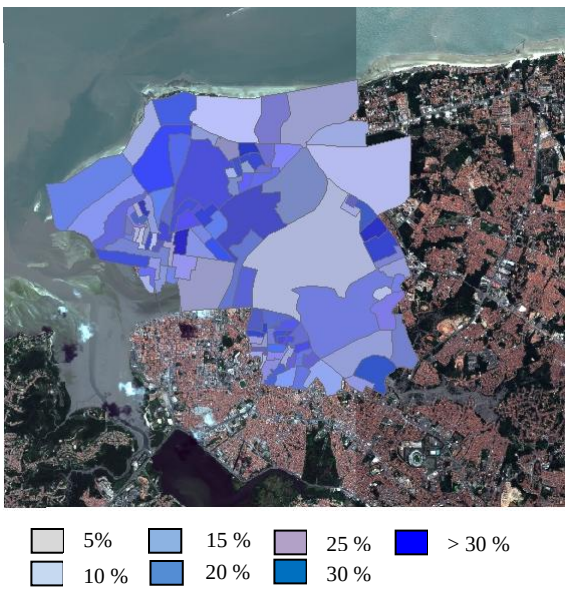


Figure 8: Percentage of mangrove fragments by city district.

At this map one perceives that very few districts have still a considerable area with mangrove fragments, mainly because of both spontaneous irregular human occupation (Figure 9) and of wood exploitation for charcoal. (Figure 10).

Figure 9: Occupation of former mangrove areas.

Figure 10: Mangrove wood stocked for charcoal.

Totally approximately 25% of the mangrove area at the northern districts from the island were devastated in the last 20 years as a consequence of urban expansion, absence of effective and efficient planning and of control actions, which would inhibit destructive actions of persons who get benefits from these activities.

CONCLUSION

The use of InterIMAGE software (image classification) and GeoDMA to elaborate the decision tree enabled a fast classification from improved image attributes, using the texture algorithm implemented at InterIMAGE allowing the separability of class mangrove. The very high spatial resolution of WorldView 2 images as well as the new spectral bands available also allowed the discrimination of different land cover classes.

The combination of spatial and spectral resolutions allows the improvement of separation among the physical characteristcs of targets to be mapped, resulting in higher detail and precision of land cover maps.

The use of spatial analysis techniques, taking into account the area of census districts, allowed the visual improvement of fragments related to districts by spatialization of data. This is of relevance for future inferences on population growth, destruction of mangrove vegetation, etc.

The results indicate that those districts which present still a considerable area of mangrove fragments are those sections managed and monitored by governmental institutions, whereas those districts with devastated fragments are typical for urban expansion areas located close to chaotic occupations.

References

BENZ, U. C.; HOFMANN, P.; WILLHAUCK, G.; LINGENFELDER, I.; HEYNEN, M., 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS Journal of Photogrammetry and Remote Sensing, v. 58, n. 3-4, p. 239-258.

BLASCHKE, T., 2010. Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry & Remote Sensing, n. 65, p. 2-16.

BÜCKNER, J.; STAHLHUT, O.; PAHL, M.; LIEDTKE., C.-E., 2001. GeoAIDA - A knowledge based automatic image data analyser for remote sensing data. In: INTERNATIONAL ICSC CONGRESS ON COMPUTATIONAL INTELLIGENCE: METHODS & APPLICATIONS, 2. Bangor, Wales,United Kingdom. Proceedings... Millet, Alberta: ICSC. p.19-22

BLASCHKE, T.; KUX, H. J. H., 2007. *Sensoriamento remoto e SIG avançados - novos sistemas sensores: métodos inovadores*: Oficina de Textos, São Paulo, 2ª ed. 303 p.

CARVALHO, M. V. A. Classificação da cobertura e uso do solo com imagens Worldview-2 utilizando mineração de dados e análise baseada em objetos 2011. 201 p. (Sid.inpe.br/MCT-m19/2011/09.05.20.27-TDI). Dissertation, MSc. In Remote Sensing) – INPE, São José dos Campos, 2011. Available at: < http://urlib.net/rep/8JMKD3MGP7W/3ACT3BL. 2012

COSTA, G. A. O. P. **A knowledge-based approach for automatic interpretation of multidate remote sensing data**. 2009. 149 p. Tese (Doutorado em Engenharia Elétrica) – Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), Rio de Janeiro, 2009.

COSTA, G. A. O. P.; FEITOSA, R. Q.; FONSECA, L. M. G.; OLIVEIRA, D.; FERREIRA, R. S.; CASTEJON, E. F., 2010. Knowledge-based interpretation of remote sensing data with the InterIMAGE system: major characteristics and recent developments. In: GEOGRAPHIC OBJECT BASED IMAGE ANALYSIS (GEOBIA), 29 jun - 2 jul 2010, Ghent, Bélgica. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVIII-4/C7. Ghent University. CD-ROM.

DIGITAL GLOBE. WhitePaper – The benefits of the 8 Spectral Bands of WorldView-II. Março, 2010a. Available at: http://Worldview2.digitalglobe.com/docs/Worldview-2_8-Band_Applications_Whitepaper.pdf . (20 Dez. 2011)

GEODMA – Geographical Data Mining Analysis. Desenvolvido por Thales Korting. Available at: http://www.dpi.inpe.br/geodma/?lingua=portugues (02 Nov. 2011).

GERCO. GOVERNO DO ESTADO DO MARANHÃO. SECRETARIA DE ESTADO DO MEIO AMBIENTE E RECURSOS HÍDRICOS**,** 1998. Macrozoneamento do Golfão Maranhense – diagnóstico ambiental da microrregião da aglomeração urbana de São Luís: estudo sócio-econômico e

cultural. São Luís: Coordenadoria de Programas Especiais/Programa Estadual de Gerenciamento Costeiro.

HAY, G.J. CASTILLA, G. Geographic Object-Based Image Analysis (GEOBIA): A new name for a new discipline. In: BLASCHKE, T.; LANG, S. HAY, G. (eds.), Object Based Image Analysis – Spatial Concepts for Knowledge-Driven Remote Sensing Applications. Berlin: Springer-Verlag, 2008. 817 p. Cap. 1.4 , pag 93 – 112.

ITT Visual Information Solutions, 2009. ENVI 4.7, version 4.7. Boulder, Colorado, EUA.

KORTING, T. S.; FONSECA, L. M. G.; ESCADA, M. I. S.; CÂMARA, G. GeoDMA: Um sistema para mineração de dados de sensoriamento remoto. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 14, 2009, Natal. **Anais...** São José dos Campos: INPE, 2009. p. 7813-7820. Available at: http://marte.dpi.inpe.br/col/dpi.inpe.br/sbsr@80/2008/11.17.21.17/doc/7813-7820.pdf. (02 Nov. 2011).

MOCHEL, F.R.C, 2006. Avaliação das potencialidades e fragilidades das áreas de manguezal para a implementação do ecoturismo usando ferramentas de sensoriamento remoto em Curupu – MA. Revista Caminhos de Geografia. São Luís, v.22, n. 17, p. 237 – 243.

PADWICK, C.; 2010. DESKEVICH, M.; PACIFICI, F. SMALLWOOD, Scott. Worldview-2 Pan Sharpening. In: **Proceedings...** ASPRS 2010 Annual Conference, San Diego, California. April 26-30.

PCI GEOMATICS ENTERPRISES INC, 2010. PCI Geomatica-10, version 10.3.1. Richmond Hill, Ontário, Canadá.

RIBEIRO, B.M.G., 2010. Avaliação de Imagens Worldview-II para o mapeamento da cobertura do solo urbano utilizando o sistema InterIMAGE. Dissertation MSc. in Remote Sensing. INPE São José dos Campos, available at: http://mtc-m19.sid.inpe.br/col/sid.inpe.br/mtc-m19@80/2010/08.03.12.52.20/doc/Dissertacao_BMGR_final.pdf.

SOUZA, M. L., 2000. *Um estudo sobre a Problemática Sócio-espacial nas Metrópoles Brasileiras.* Bertrand Brasil, Rio de Janeiro, 368p.

SOUZA, U.D.V.; FEITOSA, A.C. Ocupação e uso da zona costeira do Estado do Maranhão. In: Encontro de Geógrafos da América Latina (EGAL), 12.,2009, Montevidéu. **Anais**... XII EGAL, 2009. Trabalhos completos, p. 2415-2430. CD-ROM, On line. ISBN 78-14-00012-3. Available at: http://www.egal2009.com/ (10 Out. 211).

TOUTIN, T.; Review article: geometric processing of remote sensing images: models, Algorithms and Methods. **International Journal of Remote Sensing**, v. 25, n. 10, p. 1893-1924, May 2004.

WITTEN, I.H.; FRANK, E., 2005. *Data mining – practical machine learning tools and techniques* (2.ed.). Morgan Kaufmann, San Francisco. 558 p. ISBN (0-12-088407-0).

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