Validation of ERS-1/SAR Data to Map the Rio Amazonas Floodplain According to the Cartographic Accuracy Standards

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Abstract - The precise mapping of the border between the *Várzeas* (Floodplain) and the *Terra Firme* (Uplands) along Rio Amazonas, is of fundamental importance for any environmental study of this region. Within this frame, the objective of this study is to analyse if a section of *Várzeas*, close to the city of Santarém (Pará State, Brazil), can be mapped to an accuracy to fit the Cartographic Accuracy Standard (*Padrão de Exatidão Cartográfica - PEC)*. In this study it was verified if the border *Várzea/Terra Firme*, extracted from an ERS-1/SAR scene, texturally analysed, is compatible with PEC. To confirm the results, a TM/LANDSAT scene of this region was analysed separately and registered to the ERS-1/SAR scene. The results indicate that these products present limitations to map the floodplain at the precision required by PEC.

1.0 - INTRODUCTION

In Brazil, the Cartographic Accuracy Standard was established by Federal Government Decree Nr. 89817 on June 20, 1984, establishing the maximum acceptable errors in planimetry and height, as well as the corresponding standard error, according to the map scale. Taking into account that the literature on thematic mapping with remote sensing techniques does not consider the Cartographic Accuracy of the final product, the objective of this paper is to analyse whether a thematic map (*Várzeas*) obtained with ERS-1/SAR and TM-Landsat data, with a detailed field survey, fits the requirements for precision and accuracy of PEC. Due to the lack of plani-altimetric maps that could be used as a reference to extract the border between *Várzea* and *Terra Firme* in the area under study, systematic cartography procedures were applied. Location points of high precision, obtained by GPS and DGPS, were implanted on the extreme points of the area under study.

2.0 - DESCRIPTION OF TEST-SITE

The area under study is localized on the Rio Amazonas Floodplain, at geographical coordinates W 54°30′ - W 54°40′ and S 2°10′ - S 2° 20′. The area of interest is covered by topographic maps SA-21ZB-II (MI-474 and 475) at 1:100,000 scale, elaborated and published by DSG (Mapping Service from the Brazilian Army). This section presents an almost flat relief with several inundation lakes. The border to the *Terra Firme* is made up by a fluvial terrace, with a variable height of 10-20 m.

3.0 - CO-OCCURRENCE MATRICES AND TEXTURAL FEATURES

In the analysis of texture, the gray-level co-occurrence matrix (GLCM) is frequently used to characterize the spatial relationship of the gray level. The GLCM $P(i, j, d, \theta)$ denotes the frequency at which two gray levels i and j occur simultaneously and adjacently, at a given distance d and at a given direction θ. [1] extracted a total of 14 textural characteristics of the co-occurrence matrix. Among these, some characteristics are used extensively to obtain information from digital imagery. Among the textural characteristics defined by [1], 6 were implemented at the software package PCI EASI/PACE Radar Analysis Package, that was used in this study to work with ERS-1/SAR Data: Local Homogeneity, Contrast, Entropy, Average, Standard Deviation, Dissimilarity. A detailed description of these algorithms can be found in [2].

4.0 - MATERIALS AND METHODS

In this study geocoded digital ERS-1/SAR and georeferenced TM-Landsat data (bands 2,3,4 and 7) were used. The ERS-1/SAR data were processed with 6 *looks* to reduce the speckle effects. No specific speckle reduction filter was used, because they would reduce inherent texture of SAR images. On the other hand, according to [3], the smoothing of radar images due to the increase of *looks* is made at the expense of loss of spatial resolution. In this study however the loss of spatial resolution is not an important issue.

5.0 - PROCESSING OF SAR, TM AND FIELD SURVEY DATA

The processing of remote sensing and of field data was made following seven steps, briefly described below: 1. Geocoding of ERS-1/SAR data - The SARPPS (Preliminar Processing System) ERS-1 scene was converted to a geocoded SARGICS (Geocoded Image Correction System) at INPE. The georeferencing of ERS-1 data was made using the EASI-PACE GEOSET software, and the geographical coordinates of points in the field were determined by GPS. 2. ERS-1/SAR and TM-Landsat

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registration - Using the GCPWORKS of EASI PACE package, the TM bands 2,4 and 7 were registered to ERS-1/SAR, using 6 control points. During the resampling, the bilinear interpolation was used, because it was the procedure that showed the most natural appearance to the registered image. Due to the low quantity of control points available, a first order polynomial transform was applied. The average quadratic error of registration was ± 0,33 pixel. 3. Textural analysis of ERS-1/SAR data - ERS-1/SAR data were applied to the texture analysis algorithms mentioned above (3.0). None of these algorithms presented satisfactory results. The best result was a contrast enhancement obtained by Standard Deviation features. This scene was used to register the TM-Landsat scene to further extract the borders of interest. Figure 1 shows the SARGICS product without (left) and with (right) the Standard Deviation features. 4. Integration of ERS-1/SAR with TM-Landsat data - The method to transform IHS in RGB space (for references see, [4] and [5]). The color composite TM4(R), TM7(G) and TM2(B) was transformed to IHS space and the component Intensity was replaced by SAR. The scene obtained was converted back to RGB space. Afterwards a visual analysis was made to extract the border *Várzea/Terra Firme.* 5. Maximum likelihood classification - In order to compare results, the TM-Landsat scene was tested separately to verify its' potential for the definition of the area of *Várzeas.* A Maximum Likelihood thematic classification was applied to the composite TM3(R), TM4(G) and TM2(B), and again the border between *Várzea* and *Terra Firme* was extracted. The general precision of the classification was 93%, which is a quite reasonable result for such a complex area like the *Várzea*. 6. Edition of the reference vector - The border between *Várzea* and *Terra Firme,* plotted in the field, was converted into a text file of ARC format, type .LIN and afterwards converted in a vectorial layer that can be exhibited on a monitor. This conversion is made by the software GIS LINKS from EASI PACE. 7. Results of visual analysis - After the interpretation of SARGICS/ERS-1 and TM-Landsat scenes together and separately, each class limit was converted to a list of coordinates, in pixels and lines, which were compared to the reference vector by the calculation of the average quadratic error.

6.0 - DISCUSSION AND CONCLUSIONS

1. The quantitative analysis showed that a map at a scale 1:100,000 derived from the hybrid product SARGICS/ERS-1 and TM-Landsat, would have a better result if each one of them is compared separately. The performance of correct classification (78%), in relation to the ground truth points (70), is not sufficient to comply with PEC planimetrically, whose demand is an accuracy of 90%.

2. The map derived from the hybrid product mentioned in 1. above, could be classified as of A type, if the scale is reduced to 1:250,000.

3. The quantitative analysis also showed that the worst performance among the products studied, refers to the one derived from TM-Landsat data when used by itself. This is because the relief, with small ondulations doesn't produce shadows, and without shadows the differentiation among the different environments becomes very difficult. The vegetation cover could be another factor to differentiate among environments, and in fact it became a complicating factor. In several sections there was an "invasion" of vegetation cover from an environment over another one and, in this case, the borders detected by TM-Landsat did not correspond to the effective border among both environments (*Várzea/Terra Firme*).

4. The product SARGICS/ERS-1 analysed separately (raw or processed) didn't allow adequate discrimination of the environments studied, due to several reasons. The small wavelength (5,6 cm) allows only a little penetration into the vegetation canopy, and consequently the details of the *Várzea* morphology could not be perceived. The result of the relative uniformity of the vegetation cover and of the moisture content was a relative homogeneous radar backscatter signal for different areas.

5. The results obtained in this study did not consider the following points: (a) the errors due to georeferencing that, according to theory, are around 3 pixels; (b) the errors due to deformations of relief which was considered as perfectly flat; (c) the assumption that pixels of the features extracted from the image correspond effectively to the points found in the field, which is not the case. Nevertheless, we consider that the pixels interpreted from the features extracted from the images, correspond to the points recorded during the field survey. This approximation is necessary to reconcile this study with the demands of Decree 89.817, considering that pixels obtained with SAR data often do not to agree with ground truth. Being so, while verifying the geometrical quality of the images obtained with SAR data, this approximation cannot be accepted.

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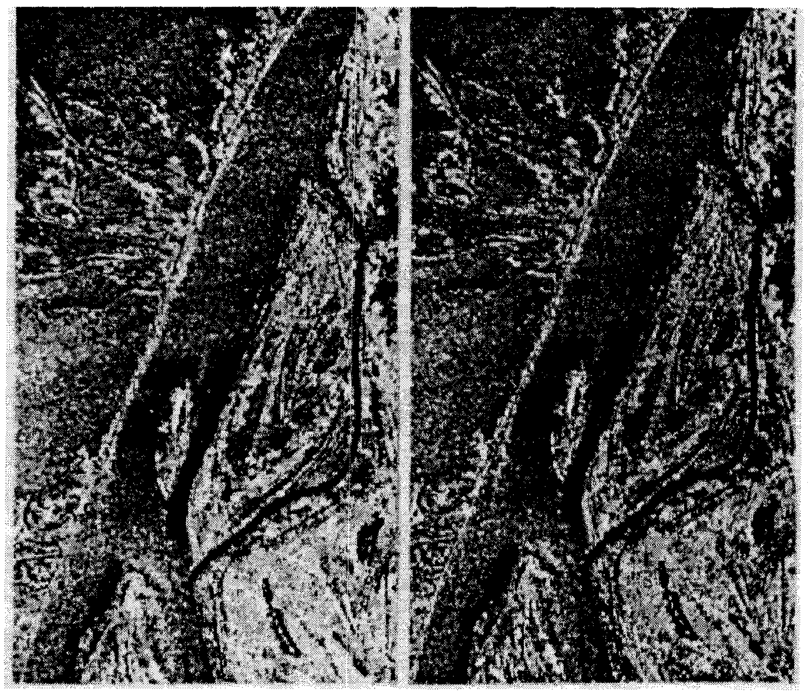

Figure 1 - Comparison between non-processed SARGICS (left) and processed (right) with Standard Deviation feature.