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14. Abstract/Notes Two image processing experiments were described using a MSS-LANDSAT scene from the Três Marias region and a SIR-A image digitized by a vidicon scanner. In the first experiment the study area was analyzed using the original and preprocessed (filtering techniques) SIR-A image data. The following thematic classes were obtained: water, dense savanna vegetation ("cerradão"), sparse savanna vegetation ("cerrado"), reforestation areas and bare soil areas. In the second experiment, the SIR-A image was registered together with MSS-LANDSAT bands 5, 6 and 7. The same 5 classes mentioned above were obtained. These results were compared with those obtained using solely MSS-LANDSAT data. As a conclusion it can be stated that the spatial information as well as coregistered SIR-A and MSS-LANDSAT data can increase the separability between classes, as compared to the use of raw SIR-A data solely.			
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EVALUATION OF SIR-A (SHUTTLE IMAGING RADAR) IMAGES FROM THE TRÊS MARIAS REGION (MINAS GERAIS STATE, BRAZIL) USING DERIVED SPATIAL FEATURES AND REGISTRATION WITH MSS-LANDSAT IMAGES
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ABSTRACT

Two image processing experiments were described using a MSS-LANDSAT scene from the Três Marias region and a SIR-A image digitized by a vidicon scanner. In the first experiment the study area was analyzed using the original and preprocessed (filtering techniques) SIR-A image data. The following thematic classes were obtained: water, dense savanna vegetation ("cerradão"), sparse savanna vegetation ("cerrado"), reforestation areas and bare soil areas. In the second experiment, the SIR-A image was registered together with MSS-LANDSAT bands 5, 6 and 7. The same 5 classes mentioned above were obtained. These results were compared with those obtained using solely MSS-LANDSAT data. As a conclusion it can be stated that the spatial information as well as coregistered SIR-A and MSS-LANDSAT data can increase the separability between classes, as compared to the use of raw SIR-A data solely.

1. INTRODUCTION

The Shuttle Imaging Radar (SIR-A), flown on board the Space Shuttle during November 1981, was the first orbital imaging radar to take images over the Brazilian territory.

Considering that the SIR-A data available was not on a digital form, it had to be digitized to be compared with MSS-LANDSAT data. Within this context, the objective of this study is the comparison between SIR-A images and MSS-LANDSAT images for land cover/land use studies, using image processing systems.

2. BRIEF DESCRIPTION OF THE STUDY AREA

The area under study (Figure 1) consists mainly of sedimentary formations (Pre-Cambrian age) including siltstones, arkoses, claystones, sandstones, slates, marls and limestones. According to Menezes et al. (1977) extensive caenozoic reworked sedimentary cover as well as alluvial and recent floodplain deposits occur within this region.

After Panoso et al. (1978) the following soil types predominate in the study area: dark-red dystrophic latosols, dystrophic cambisols and litolic soils associated with different lithologies, relief forms and vegetation types.

The digital classification of a MSS-LANDSAT scene (date: August 27, 1978) allowed the obtainment of 4 main classes of land cover/land use which will be succinctly described below:

1. Cerradão (also known as Sclerophyllous woodland after Bourlière, 1983) is commonly composed of up to 3 different strata, namely:

1. short grass and forbs stratum;
2. shrubs and low trees stratum;
3. a tree stratum 5-6 m high with curved trunks mostly hardwood.

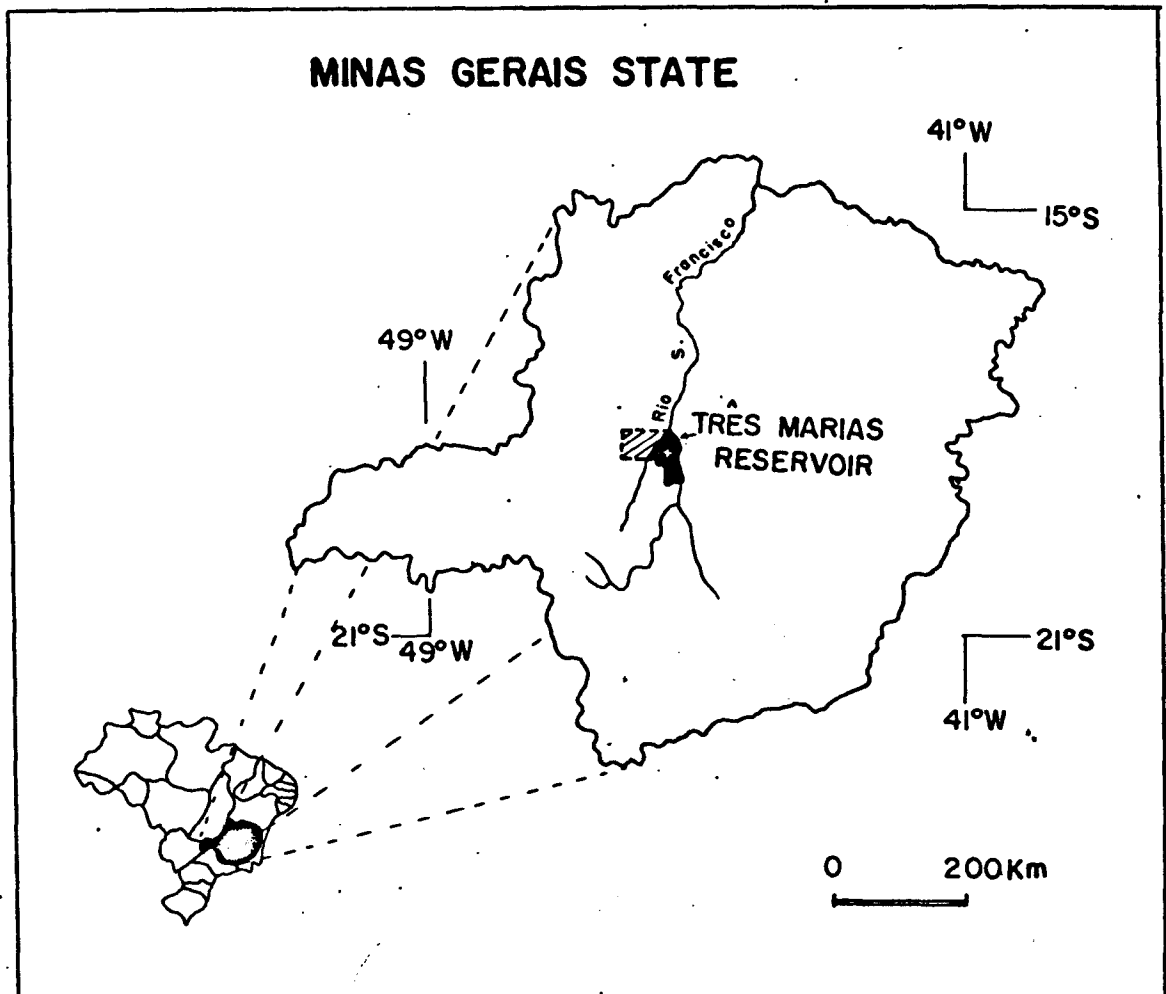


Fig. 1 - Localization of the study area.

Within the study area, "cerradão" occurs most conspicuously on the southern part of the Três Marias hydroelectrical power plant, over gently rolling terrain. According to Panoso et al., dark red dystrophic latosols with clay texture are the predominant soil type in this section.

2. Cerrado

"Cerrados" constitute, within the study area, an extensive savanna vegetal formation, intensively changed due to clear cuts and grass burnings. Four main physiognomic savanna types can be identified in the field: savanna grassland ("campo limpo"), tree and/or shrub savanna ("campo sujo"), wooded savanna ("campo cerrado") and savanna woodland ("cerrado"). Cerrados occur most frequently on very hilly terrain over litolic soils and associations of litolic soils with dystrophic cambisols.

3. Bare soil areas

These areas which were formerly deforested and burnt down, are located predominantly over scarped hills and litolic soils. Due to its intensive use as pastureland or for charcoal obtainment activities, the vegetation cover of this area is almost inexistent, originating soil erosion processes.

4. Reforestation areas

Reforestation areas constitute small sections, normally located over deep soils. Within the area under study, the reforestation is made essentially with Eucalyptus. This has caused serious problems of soil nutrients exhaustion.

For further information on the area under study, see Sausen (1981) who made a comprehensive study on correlations between relief, geology, soils, vegetation and drainage from the upper Rio São Francisco basin, including the Três Marias region, using MSS-LANDSAT.

3. METHODOLOGY

The problems concerning digital classification normally involve multispectral images. As for SIR-A, there is originally just one channel which includes spectral as well as spatial information. The latter one may be extracted to help on the class discrimination procedures. Besides that, additional information from other sources can be added to this channel; e.g. LANDSAT-MSS: several MSS channels can be coregistered with SIR-A data.

This study is constituted by 2 experiments on processing of digital data using a SIR-A image digitized by a vidicon scanner (General Electric), coupled to the imaging system IMAGE-100 from INPE. At the first experiment 3 channels were used with the following arrangement: on the first channel the digitized SIR-A data were stored; the second was the original SIR-A channel processed by a low-pass filter to extract the information related to the clustering characteristics of thematic classes (Dutra & Mascarenhas, 1984). The third finally consists of the first channel processed by a high-pass filter to enhance the information on relief roughness. The low-pass filter used, developed by Dutra & Mascarenhas (1984), is graphically represented on Figure 2. This filter corresponds to an average in a region of 5 by 5 pixels.

$$\frac{1}{21} \begin{bmatrix} 01110 \\ 11111 \\ 11111 \\ 11111 \\ 01110 \end{bmatrix}$$

Fig. 2 - Low-pass filter.

To extract roughness information a heuristic filter called "variation" (after Schachter et al., 1979) was used. Considering a neighborhood of 3 by 3 around a pixel and labeling the pixels of this neighborhood by

a b c
d x e
f g h

we get that the total variation (TV) is the sum of vertical variation (VV) and horizontal variation (HV), namely:

$$\begin{aligned}
 VV &= |a-d| + |b-x| + |c-e| + |d-f| + |x-g| + |e-h| \\
 HV &= |a-b| + |d-x| + |f-g| + |b-c| + |x-e| + |g-h| \\
 TV &= VV + HV
 \end{aligned}$$

The digital filtering is a procedure to extract the spatial attributes since the content of spatial frequency expresses, in a certain way, the spatial relationship between the pixels (Dutra & Mascarenhas, 1984). The combination of the 3 channels created at the first experiment allowed a digital classification, using a maximum likelihood algorithm developed by Velasco et al. (1978). Five thematic classes ("cerrado", "cerradão", exposed soil, reforestment and water) were obtained. Besides that, the classification matrices of the test-sites and training areas were obtained, which are analyzed on item 4 of this study.

At the second experiment the original SIR-A channel (first channel of the first experiment) was coregistered to MSS-LANDSAT channels 5, 6 and 7, using an affine transformation (first grade polynomial). The same 5 classes mentioned above were obtained using the same classifier.

4. DISCUSSIONS OF RESULTS

The values of average performance (AP), average confusion (AC) and average rejection (AR) are listed on Tables 1 and 2. They are related to training and test areas referring to the SIR-A data used at the first experiment¹.

TABLE 1
EVALUATION OF TRAINING AREAS, FIRST EXPERIMENT

THRESHOLD	ORIGINAL SIR-A CHANNEL		3 SIR-A (*) CHANNELS	
	5	6	5	6
AP (%)	79,3	79,3	85,3	85,6
AR	0,0	0,0	1,1	0,3
AC	20,7	20,7	13,6	14,1

(*) The 3 channels considered are: 1) original SIR-A channel; 2) VARIHV S with MD5FIL 2 B = C = 1 (low pass filter); 3) MD5FIL 2 B = C = 1 (high pass filter).

¹ Average performance is defined as the average percentage of correct classification for each area (training or test), weighted by the number of points in the area. Analogous definitions are valid for average confusion and average rejection, substituting correct classification by classification error and rejection, respectively.

TABLE 2
EVALUATION OF TEST AREAS, FIRST EXPERIMENT

	ORIGINAL SIR-A CHANNEL		3 SIR-A CHANNELS	
THRESHOLD	5	6	5	6
AP (%)	72,3	72,3	76,9	77,2
AR	0,0	0,0	2,2	0,5
AC	27,7	27,7	20,9	22,3

The relatively high AP values for both training and test areas demonstrate the usefulness of SIR-A data for digital classification purposes. Furthermore it is noted that the use of spatial information (the use of low-pass and high-pass filters) improve the classification results.

At the second experiment (see Tables 3 and 4) the main interest was to analyze the possibilities of merging and conjunct use of SIR-A and MSS-LANDSAT data.

TABLE 3
EVALUATION OF TRAINING AREAS, SECOND EXPERIMENT

	A		B	
	SIR-A AND MSS MERGED CHANNELS		MSS CHANNELS 4, 5, 6, 7	
THRESHOLD	5	6	5	6
AP (%)	95,2	95,7	91,0	91,8
AR	0,7	0,3	1,1	0,3
AC	4,1	4,0	7,9	7,9

TABLE 4
EVALUATION OF TEST AREAS, SECOND EXPERIMENT

	A		B	
	SIR-A AND MSS MERGED CHANNELS		MSS CHANNELS 4, 5, 6, 7	
THRESHOLD	5	6	5	6
AP (%)	87,6	90,5	91,3	92,2
AR	4,6	0,2	1,2	0,3
AC	7,8	9,3	7,5	7,5

Comparing the 4 tables one can observe that a conjunct use of SIR-A and MSS-LANDSAT data improved the average performance at training areas.

On the other hand, the average of test areas (Table 4A) is lower if compared to the exclusive use of MSS (Table 3B and 4B) data. Apparently this lower performance, as shown on Table 4A, is an indication of a problem related to the extension of the spectral signature per class. This is probably related to factors which changed the spectral response of the radar return signals for the same class. Additionally, the scanner process used to convert the radar image to digital form can induce degradations due to spatial nonlinearities of the scanner equipment.

Besides that, eventually residuals of the geometric correction procedures used have contributed to confound the considered classes.

We believe that a more detailed study on the applicability of SIR-A data to the land cover classes used, will provide further information to optimize digital classifications of this orbital imaging radar. Within this context, the use of the technique of feature selection to choose the 4 most informative channels, seems to be recommended as it was demonstrated in some preliminary inedited experiments.

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