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Application of the Semivariogram Textural Classifier (STC) for Vegetation Discrimination Using JERS-1 SAR Data of the Uaupés River (Northwestern Brazil)

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Abstract. Classification of JERS-1 SAR data from the remote, heavily-vegetated and cloud-covered area of the Uaupés River (northwestern Brazil) was carried out using the semivariogram textural classifier (STC). Such a geostatistical classification approach permitted vegetation units and water bodies to be discriminated and tentatively mapped, suggesting this is a promising approach for environmental monitoring of rainforest regions using JERS-1 SAR data.

Keywords: JERS-1, radar

1 Introduction

JERS-1 SAR data (path 430/row 300) were acquired over the Uaupés River region (northwestern Brazil) on 20 June 1992. These images were processed at level 2.1 (standard geocoded image resampled to UTM projection). The study area is remote and heavily-vegetated with predominantly flat topography and persistent cloud cover (Fig.1). Miranda et al. (1994 and 1995) have shown that the JERS-1 SAR image representation of each cover type northeast of the investigated site (near the confluence of the Içana and Piraiauara rivers) has a distinctive semivariogram. This fact made feasible the determination of vegetation types and water bodies by means of the semivariogram textural classifier (STC). Similar conclusions were drawn by Miranda and Carr (1994) through the analysis of SIR-B data of such an area using STC. The objective of the research is to verify if the geostatistical classification approach used the Içana River region can also be applied to JERS-1 SAR data obtained over the Uaupés River.

2 Cover types and scattering mechanisms

Within the study area, the backscattered energy measured by the JERS-1 SAR antenna is primarily influenced by the following environmental conditions: (1) the topography is predominantly flat, hence there is a negligible modulation of the radar backscatter by slope effects; (2) the cover types are composed of vegetation and water. These characteristics are similar to those found in the Içana River region.

Vegetation units were visually distinguished on the JERS-1 SAR image as groups of pixels with similar DN values over extended areas. The mapped vegetation units are dense vegetation, open vegetation and flooded vegetation. Water is included as an additional surface cover type. Scattering mechanisms and related JERS-1 SAR image signatures are summarized in Table 1

3 Analysis of semivariogram behavior

Data sets for calculations of isotropic semivariograms (hereafter referred to as training masks) were extracted from the portion of the JERS-1 SAR image corresponding to the study area (Fig. 2). The size of all training masks is 22 by 22 pixels. DN statistics (mean and variance) for the training masks are shown in Table 2.

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Cover Type	Scattering Mechanism	DN Value	Image Tone
Water	Specular Reflection	Very Low	Very Dark
Open Vegetation	Single Foward Scattering Predominates Over Diffuse Backscatter	Low	Dark
Dense Vegetation	Diffuse Backscatter	Intermediate	Intermediate
Flooded Vegetation	Double Foward Reflection (double-bounce effect)	Very High	Bright

Table 1 - Cover types and related signatureson the JERS-1 SAR image

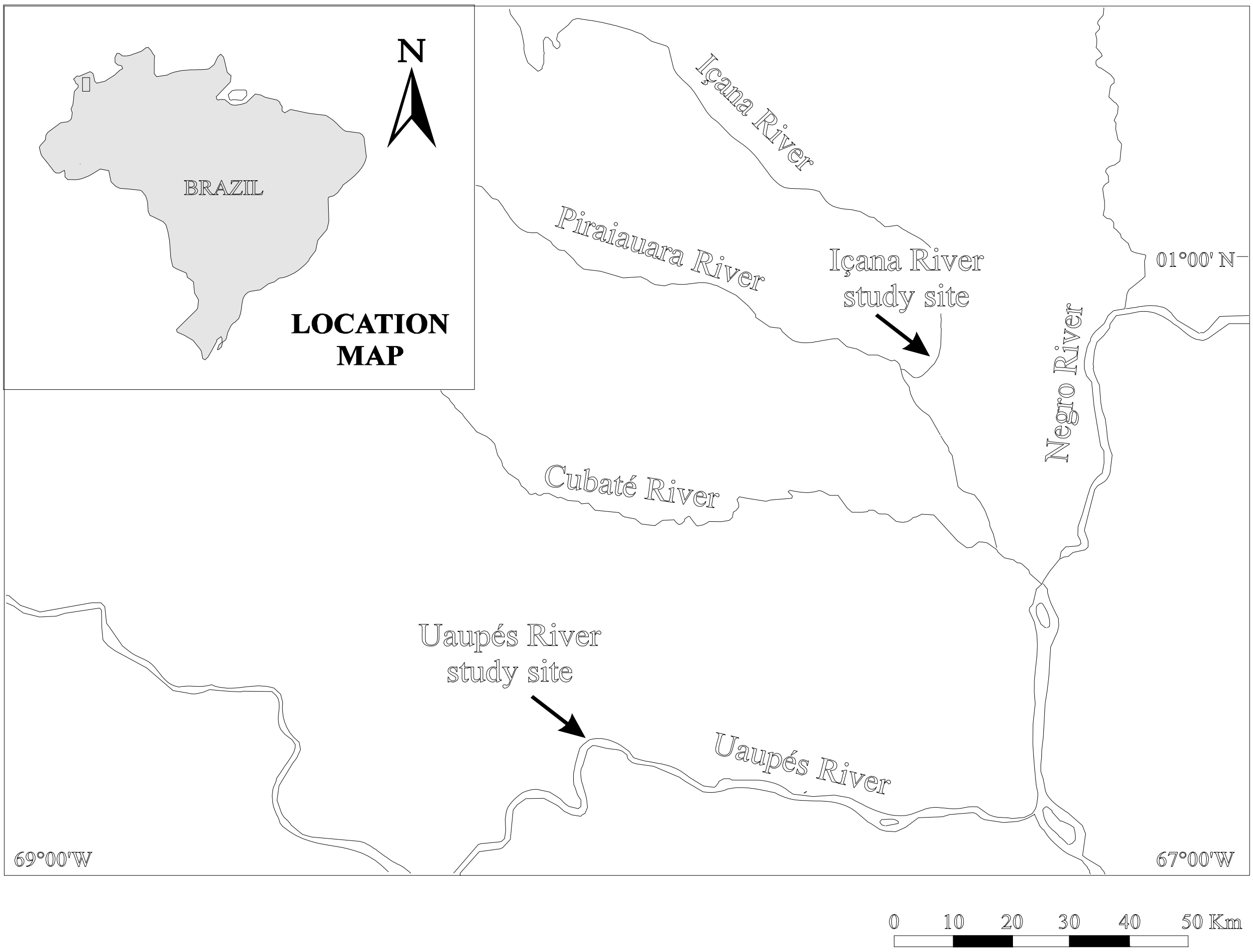

Fig. 1 - Location Map of study area.

Surface Cover Type	DN Mean	DN Variance
Water	29.09	181.19
Open Vegetation	81.55	779.35
Dense Vegetation	111.46	1474.38
Flooded Vegetation	144.38	2526.71

Table 2 - Statistical moments of water and vegetation training masks (Uaupés River)

	Water	Open vegetation	Dense vegetation	Flooded vegetation
Water	0.55	0.00	0.00	0.00
Open vegetation	0.00	0.63	0.07	0.00
Dense vegetation	0.00	0.11	0.60	0.18
Flooded vegetation	0.00	0.00	0.17	0.61
Unclassified pixels	0.45	0.26	0.16	0.21
Total	1.00	1.00	1.00	1.00

Table 3 - Confusion matrix for STC classification of the different cover types (Uaupés River)

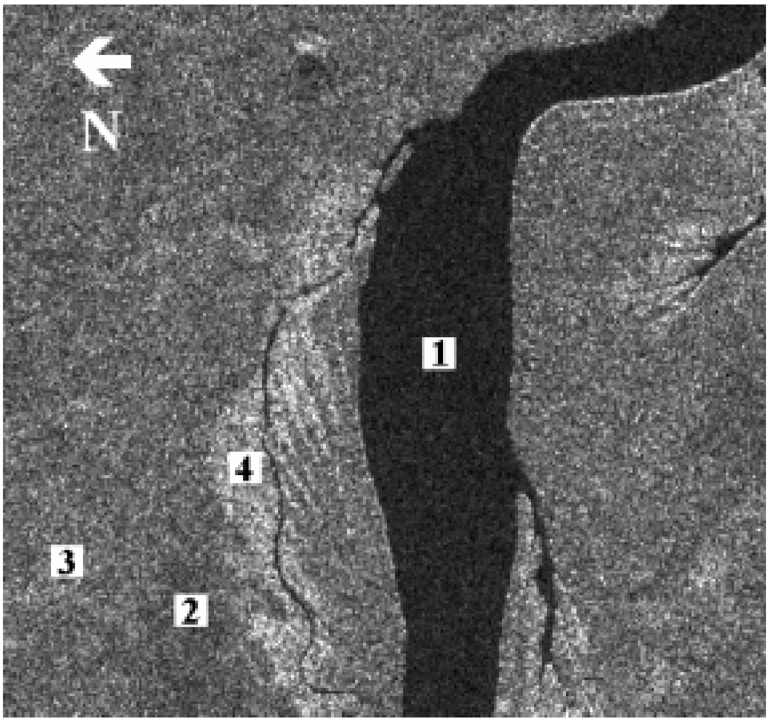

Fig. 2 - JERS-1 SAR image of the study area (Uaupés River, nothwestern Brazil). This is a portion of a JERS-1 SAR scene with JERS-1 Ground Reference system grid coordinates of path 430 and row 300. Image size is 480 by 512 pixels (6.0 by 6.4 Km). Training masks: water (1), open vegetation (2), dense vegetation (3), and flooded vegetation (4). Photo credit: NASDA/MITI (1992). See Fig1 for location.

Results obtained for separation distances up to 22 pixels (Fig. 3) indicate that each cover type in the study area has a distinctive semivariogram:

a. Water: the semivariogram of water is essentially flat, exhibiting behavior similar to that expected for a random data set. There is a subtle drop from the random expectation at a lag distance of 1 pixel, but for greater lag distances the semivariogram coincides with the estimated sill. A similar shape was described by Miranda et al. (1994 and 1995) for the water semivariogram calculated from JERS-1 SAR data of the Içana River (Fig. 4).

b. Open vegetation: this semivariogram is higher than t he previous one, due to the increased variance of open vegetation in relation to water. A nugget effect is observed (there is an apparent failure of the semivariogram to go through the origin, where the lag distance is zero). Subsequently, the semivariogram rises smoothly upwards to a lag distance of 2 pixels, curving to a flat plateau fairly coincident to the estimated sill. This behavior indicates that this cover type has a spherical structure showing a nugget effect, as also suggested by Miranda et al. (1994 and 1995) for the open vegetation semivariogram portrayed in Fig. 4.

c. Dense vegetation: the semivariogram for dense vegetation also displays a spherical shape with indication of a nugget effect. For lag distances greater than 2 pixels, the semivariogram has only minor fluctuations around the estimated sill. The overall shape of this semivariogram resembles the one pertaining to dense vegetation in Fig. 4.

d. Flooded vegetation: flooded vegetation presents the highest variance among the cover types of the study area (Table 2) and is associated with the highest values of the semivariogram function in Fig. 3. A nugget effect is also observed on the semivariogram of this cover type. Differently from what is portrayed for flooded vegetation in Fig.4, this semivariogram does not show a wave shape. It rises steadily upwards and approaches the estimated sill only at lag distances greater than 15 pixels. It should be pointed out that the nugget effect shown in semivariograms of Fig. 3 can be explained by the presence of speckle, which was also reported by

Miranda et al. (1994 and 1995) to cause the nugget effect in semivariograms of Fig. 4.

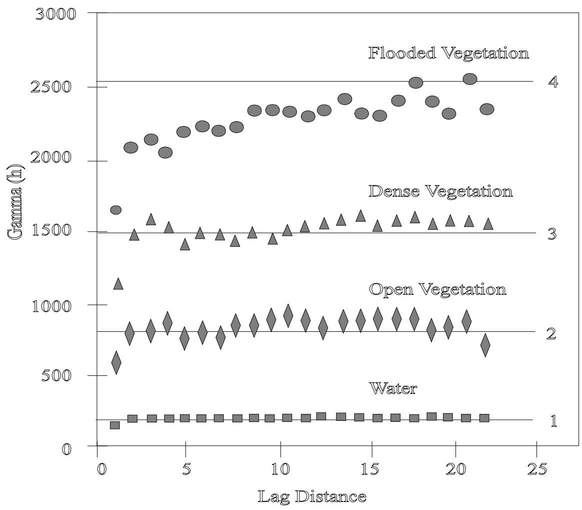

Fig 3 - Semivariograms of training masks extracted from JERS-1 SAR data (Içana River). Estimated sill (=DN variance of training mask). 1-Water (181.19); 2-Open Vegetation (779.35); 3-Dense Vegetation (1474.38); 4-Flooded Vegetation (2526.71).

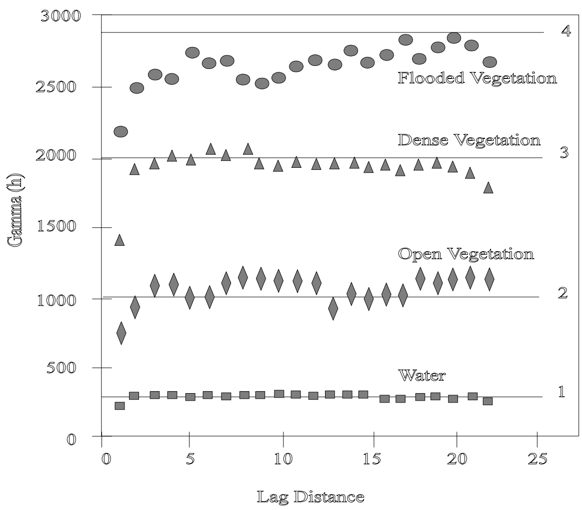

Fig 4 - Semivariograms of training masks extracted from JERS-1 SAR data (Içana River). After Miranda et al. (1994 and 1995). Estimated sill (=DN variance of training mask). 1-Water (282.32); 2-Open Vegetation (986.17); 3-Dense Vegetation (1990.89); 4-Flooded Vegetation (2907.81).

4 The semivariogram textural classifier (STC)

The JERS-1 SAR image representation of each cover type in the study area has a distinctive semivariogram, what recommends the application of STC to the Uaupés River data set. A similar reasoning was presented by Miranda et al. (1994 and 1995) to justify the use of such a geostatistical classification approach to the JERS-1 SAR data acquired over the Içana River. STC is a supervised parallelepiped type classifier with a minimum distance to mean check for overlapping classifications (MacDonald et al., 1990). It is a strictly deterministic classifier and therefore provides the option of combining textural and radiometric information. Textural information is expressed by the spatial structure of the image representation of a surface cover type (which is described by the shape and value of the semivariogram function). Radiometric information is conveyed by the mean DN value of the cover type.

The classification process consists of two major tasks: training and classification. The training masks (22 by 22 pixels) used in the training task were the ones shown in Fig. 2. STC calculated a semivariogram within a moving window (7 by 7 pixels) for each pixel in the training mask. This procedure resulted in a mean semivariance and a standard deviation value for each lag distance (up to six) in each class. A mean and a standard deviation were also calculated for the DN values of each class. The training masks and moving window used in this paper have the same size as the ones utilized by Miranda et al. (1994 and 1995).

The classification task began with the definition of parallelepiped boundary conditions (PPD) for each class (Fig. 5) based upon a multiple of the standard deviation from the mean. In this paper, such a value is 1.50, which was also the multiplier used by Miranda et al. (1994 and 1995). Then, beginning in the upper left corner of the image, a semivariogram was calculated for the window surrounding each pixel (keeping the same dimension as the moving window used in the training task). The resulting semivariogram and DN value of the central pixel were compared with the PPD values. If the value for each lag distance and the DN were situated between the minimum and maximum boundaries for any class, then the pixel was defined as belonging to that class. In the event of an overlapping classification, a minimum distance to mean calculation was performed for each possibility, with the lowest value determining the assigned class.

5 Results of STC classification

STC classification results of the JERS-1 SAR image of the study area (Fig. 2) are shown in Fig.5. Pixels classified as water (dark gray) clearly outline the course of the Uaupés River. The location of flooded vegetation (white) is restricted to areas of alluvial influence aloug the Uaupés River and its tributaries, where standing water beneath the canopy exists (which cause the double-bounce effect of microwave energy back to the JERS-1 SAR antenna). Areas of predominantly open vegetation (light gray) are interpreted to be located in dry depressed zones. Dense vegetation (gray) occurs interspersed with open vegetation in watershed areas.

The confusion matrix for the training masks used in STC classification is shown in Table 3. As can be seen from the table, classification accuracy is 55 per cent for water, 63 per cent for open vegetation, 60 per cent for dense vegetation and 61 per cent for flooded vegetation. Misclassification is observed only for vegetation classes that show adjacent semivariograms in Fig.3: open vegetation (11 per cent) classified as dense vegetation; dense vegetation (7 per cent) classified as open vegetation; dense vegetation (17 per cent) classified as flooded vegetation; flooded vegetation (18 per cent) classified as dense vegetation. A large percentage of pixels (45 per cent) in the water training mask is labelled as unclassified. Training masks for open, dense and flooded vegetation have less unclassified pixels than water (26, 16 and 21 per cent, respectively).

Similar results are observed through the examination of the confusion matrix for STC classification of the Içana River area (compare tables 3 and 4). Classification accuracy is 58 per cent for water, 67 per cent for open vegetation, 68 per cent for dense vegetation and 60 per cent for flooded vegetation. Misclassification is observed only for vegetation classes that show adjacent semivariograms in Fig. 4: open vegetation (7 per cent) classified as dense vegetation; dense vegetation (8 per cent) classified as open vegetation; dense vegetation (3 per cent) classified as flooded vegetation; flooded vegetation (13 per cent) classified as dense vegetation. A large percentage of pixels (42 per cent) in the water training mask is labelled as unclassified. Training masks for open, dense and flooded vegetation have less unclassified pixels than water (26, 21 and 27 per cent, respectively).

6. Conclusions

This paper demonstrates that the representation of each cover type in the JERS-1 SAR image of the study area has a distinctive semivariogram signature. Similar conclusions were drawn by Miranda et al. (1994 and 1995) for the semivariogram analysis of JERS-1 SAR data of the Içana River (northeast of the investigated site). Results have shown that STC allows vegetation units and water bodies to be discriminated and tentatively mapped. Similarities between the confusion matrices for the training masks used in STC classification of JERS-1 SAR images of the Uaupés and Içana rivers suggest this is a promising approach for environmental monitoring of rainforest regions of the world.

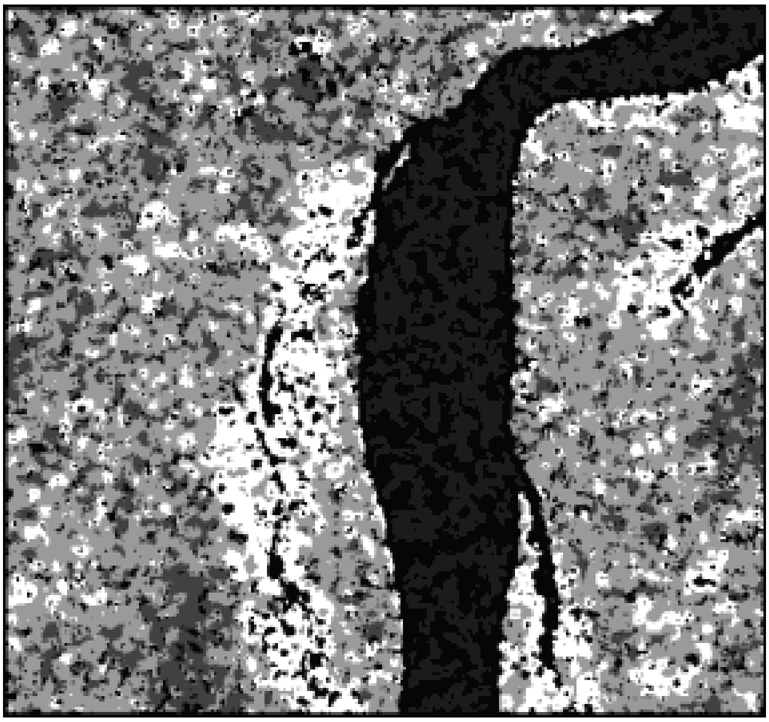

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Fig. 5 - STC classification results. Black=unclassified pixels; Dark gray=water; Gray=open vegetation; Light gray= dense vegetation; White=flooded vegetation.

Water	0.58	0.00	0.00	0.00
Open vegetation	0.00	0.67	0.08	0.00
Dense vegetation	0.00	0.07	0.68	0.13
Flooded vegetation	0.00	0.00	0.03	0.60
Unclassified pixels	0.42	0.26	0.21	0.27
Total	1.00	1.00	1.00	1.00

Table 4 - Confusion matrix for STC classification of the different cover types (Içana River)

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