

**Window size selection for texture image generation from SAR data:
a case study for a Brazilian Amazon test site**

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Abstract. The goal of this paper is to test several window sizes for generation of SAR texture images. Two JERS-1 and one Radarsat images were used. A total of 69 known targets in Rondônia State, Brazilian Amazon were used and classified in six cover classes. Five window sizes - 5x5, 7x7, 9x9, 11x11 and 15x15 pixels - were tested. Fourteen texture images were generated for each window size, resulting in 210 texture images. For all these images Mahalanobis distances we computed for each paired cover classes. For JERS-1 the best window sizes were 7x7 and 11x11. Regarding the Radarsat image, the largest window size (15x15) used appears to be small, denoting that greater window sizes might be tested. The best discrimination, for JERS-1 images, was between recent deforestation and pasture, while Radarsat presented best discrimination between pasture and mature forest. JERS-1 showed to be better than Radarsat for land cover mapping.

Keywords: SAR, window size, texture measures, Amazonia

1 Introduction

The tropical rain forest plays an important role in the biogeochemical, hydrological and climatic cycles. A large amount of CO₂ is launched into atmosphere because of biomass burning, following deforestation (Schimel *et al.*, 1995).

Since the 70's, optical remotely sensed data has been used for monitoring of natural areas. These data have been used for land cover/land change mapping, allowing the identification of several cover classes like crop fields, bare soil, pasture, secondary forest and mature forest. In some regions, the high cloud cover is a limitation for using optical data. An example is the last mapping of deforestation on the Brazilian Amazon Basin (INPE, 1998), where the Amapá State could not be mapped due to the absence of low cloud cover images.

Synthetic Aperture Radar (SAR) images have been used as an alternative source of data for land cover mapping. Luckman *et al.* (1997) studied the relationship between backscatter and regenerating forest biomass and found that these data could provide useful information for

above-ground biomass estimation. Rennó and Soares (1996), using SIR-C/X-SAR for crop discrimination at Pernambuco State, Brazil, found that the classification accuracy assessed by the *Kappa* coefficient of agreement reached up to 0.9 when several texture measures were used. Rignot *et al.* (1996) used SIR-C and Landsat TM data for deforestation and secondary growth mapping in Rondônia/Brazil and found that multi-band cross-polarized SAR data were important for classification. Yanasse *et al.* (1996) tested the relationship between regenerating stages and SIR-C (L-band, C-band, cross-polarized) data, and noticed that the coefficient of variation for L-HH and L-HV data presented an inverse relationship with regeneration stages.

Tonal and textural information have been used for explore better SAR data. Sant'Anna *et al.* (1996) used the Frost filter, Coefficient of variation and the α parameter of κ -amplitude distribution. They classified a subset of a Radarsat image using three different algorithms: a) maximum likelihood, b) Interacted Conditional Modes (ICM) and c) region growing segmentation/Bhattacharya. The authors concluded that, for mapping bare soil/pasture, secondary forest and mature forest the best *kappa* value were found when Frost and α parameter filtered images were classified by ICM algorithms.

From the above, it is evident that the importance of using textural measures for SAR classification. These measures may be obtained using filtered images with a moving window of a certain size. However the proper size of the window is dependent on the used measure, on type of application and on the used data.

In this work five window sizes are investigated and used on the generation of Haralich's texture images, from two JERS-1 (L-band, HH) and one Radarsat (C-band, HH) data, in order to SAR classification and land cover mapping.

2 Test site and ground truth

The test site is located at Rondônia State, western Brazilian Amazon, with central coordinates S09°30'/W62°50' (**Figure 1**). The region presents a slightly undulated terrain, with an average annual rainfall of about 2,200mm, mean annual temperature of 23,6°C (H.Schimitz, unpublished data), and a dry season from late April to late August.

After the 70's decade the settlement of small farmers began along the BR-364 highway. As a consequence forest has been clear cut to allow crop fields and pasture establishment. Deforested land is used for some years and when soil loses its fertility the areas are sometimes abandoned, leading to forest regeneration (Uhl *et al.*, 1988).

Aerial reconnaissance was performed during the first survey on July/96 and about a hundred aerial photos at 1:15,000 scale were taken. During September/96, several targets of interest were visited, GPS coordinates along the roads were taken, and the land cover for each target was analyzed. Interviews with local people have been made, asking about the age of secondary forest areas and management techniques.

3 Land cover and regeneration stages map generation

A Regeneration-stage map was built using multi-temporal series of Landsat images from 1985 to 1996. These images were registered using the Landsat 1995 image as the reference. The ENVI

(Environment for Visualizing Image) system was used to perform this task. Target contours were digitized on the screen, over a subregion of 24x18 km and cover classes were assigned to each region defined by the contours. The cover classes of interest were: a) RD: recent deforestation, b) PA: pasture/bare soil, c) YSF: young secondary forest (2-4 years), d) ISF: intermediate secondary forest (5-8 years), e) OSF: old secondary forest (9-13 years) and f) MF: mature forest. Aerial photos and GPS coordinates were also helpful in the map generation. **Figure 2** shows the target contours superimposed on Landsat TM5 1996 imagery, as well as their cover classes. **Table 1** presents a list of the cover classes, their number of targets and total area per class.

Table 1: Survey fields summary for six studied cover classes

COVER CLASS	# of targets	# of pixels	Area (ha)
1) Recent Deforestation (RD)	5	6,448	580.32
2) Pasture or bare soil (PA)	17	12,883	1,159.47
3) Young Secondary Forest (YSF)	11	5,109	459.81
4) Intermediate Secondary Forest (ISF)	9	4,872	438.48
5) Old Secondary Forest (OSF)	23	12,927	1,163.43
6) Mature Forest (MF)	4	30,557	2,750.13
Total	69	72,796	6,551.64

4 SAR data set

In this work, two JERS-1 (L-band, HH-polarized) and one Radarsat (C-band, HH-polarized) amplitude images were used. The imaging date were May 28 and July 11, 1996 for JERS-1 images and August 19/1996 for the Radarsat image. These images presents 12.5m of pixel spacing, and are on 16 bits format. JERS-1 was generated by National Space Development Agency of Japan (NASDA) and Radarsat was generated by Canadian Center for Remote Sensing (CCRS).

5 Image processing

JERS-1 and Radarsat data were read using ENVI and PCI systems, respectively. Both images were firstly converted from 16 to 8 bits to save disk space and to turn computer processing easier. SAR images were registered using the Landsat 1995 image as the reference. As Landsat images presents 30m resolution, all three SAR images were also converted to this same resolution, using a linear transformation and nearest neighbor resampling. A subset image of 800x600 pixels was selected for each SAR data, containing 69 targets.

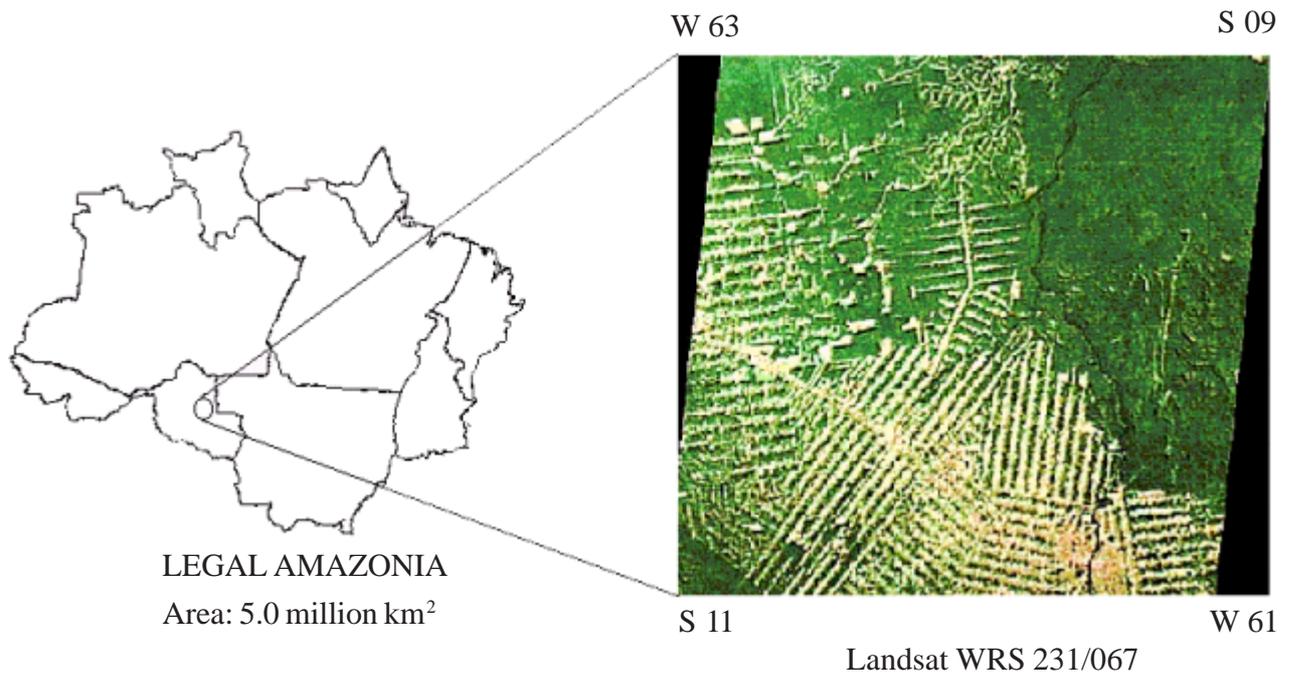


Figure 1: Test Site Location and Landsat Thematic Mapper Image (WRS 231/067).

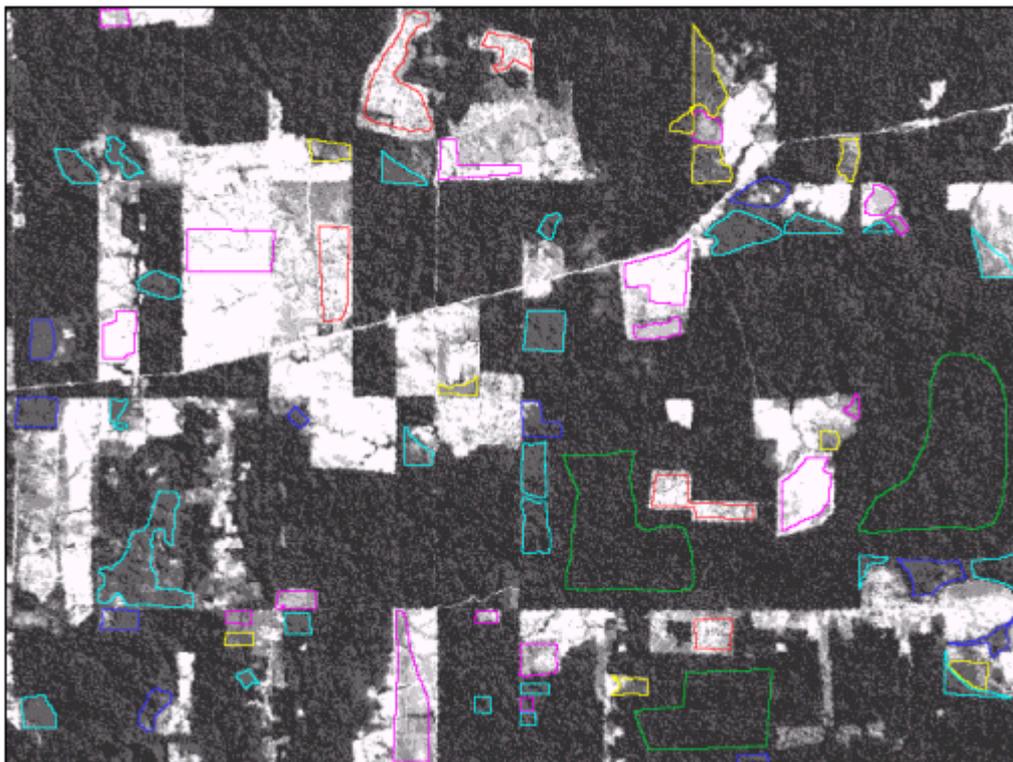


Figure 2: Target contours superimposed on Landsat TM5 band (1996) image. Legend: ●-RD (Recent Deforestation), ●-PA (Pasture), ●-YSF (Young Secondary Forest), ●-ISF (Intermediate secondary Forest), ●-OSF (Old Secondary Forest), ●-MF (Mature Forest)

6 Texture image generation

For each SAR image fourteen Haralick's texture images were generated, based on the Gray Level Co-occurrence Matrices (GLCM). Soares *et al.* (1997) presented a review for the used textures here. Five window sizes were used: 5x5, 7x7, 9x9, 11x11 and 15x15 pixels. It were generated 14 (textures) x 5 (window sizes) x 3 (SAR image), with a total of 210 texture images. These 210 texture images were normalized to have mean zero and unitary standard deviation. **Table 2** presents a list with all texture measures and the average value calculated per cover classes, using July 11/JERS-1 data and the 11x11 moving window. Results presented on **Table 2** will be discussed on future works. **Figure 3** shows some illustrative color composition of texture images for JERS-1 (July 11) and Radarsat (August 19) data.

Table 2: Average texture measures for each cover class, computed using 11x11 window size and the JERS-1 image obtained on July 11, 1996.

Haralick's Texture Measures	COVER CLASSES					
	RD	PA	YSF	ISF	OSF	MF
1) Mean (mean)	1.23	-1.33	0.02	0.20	0.26	0.53
2) Variance (vari)	0.70	-1.28	-0.01	0.20	0.12	0.36
3) Energy (ener)	2.25	0.17	-0.03	0.20	-0.02	0.04
4) Correlation (corr)	-0.36	0.93	-0.03	-0.04	-0.21	-0.45
5) Entropy (entr)	0.05	0.17	0.20	0.18	0.20	0.19
6) Contrast (cont)	0.78	-1.35	-0.01	0.18	0.16	0.50
7) Homogeneity (homo)	1.63	0.75	-0.02	0.24	-0.09	-0.10
8) Dissimilarity (diss)	0.65	-1.06	0.07	0.20	0.21	0.46
9) Mean of sum vector (smea)	1.13	-1.34	0.03	0.20	0.27	0.53
10) Variance of sum Vector (svar)	0.37	-1.09	0.02	0.19	0.09	0.21
11) Entropy sum vector (sent)	0.14	-0.02	0.18	0.18	0.19	0.20
12) Mean of difference Vector (dmea)	0.65	-1.06	0.07	0.20	0.21	0.46
13) Variance difference Vector (dvar)	0.69	-1.27	0.02	0.20	0.16	0.44
14) Entropy difference Vector (dent)	0.23	-0.12	0.17	0.19	0.20	0.24

RD=Recent Deforestation

PA=Pasture or bare soil

YSF=Young Secondary Forest

ISF=Intermediate Secondary Forest

OSF = Old Secondary Forest

MF = Mature Forest

7 Results

The Mahalanobis distances (D2) were computed for all two-by-two cover classes combination for each window size and texture measures. The SAS (Statistical Analysis System) software was used to compute all D2 values. Small values of D2 denote that two classes are similar, or can not be discriminated, and large values of D2 mean that the pair of classes are dissimilar or well discriminated. **Figures 4** and **5** show D2 values obtained for some paired cover classes for JERS-1 data recorded on May 28 and July 11, respectively, and **Figure 6** presents the same results obtained for Radarsat data. Paired cover classes with D2 less than 2.0 were not presented here.

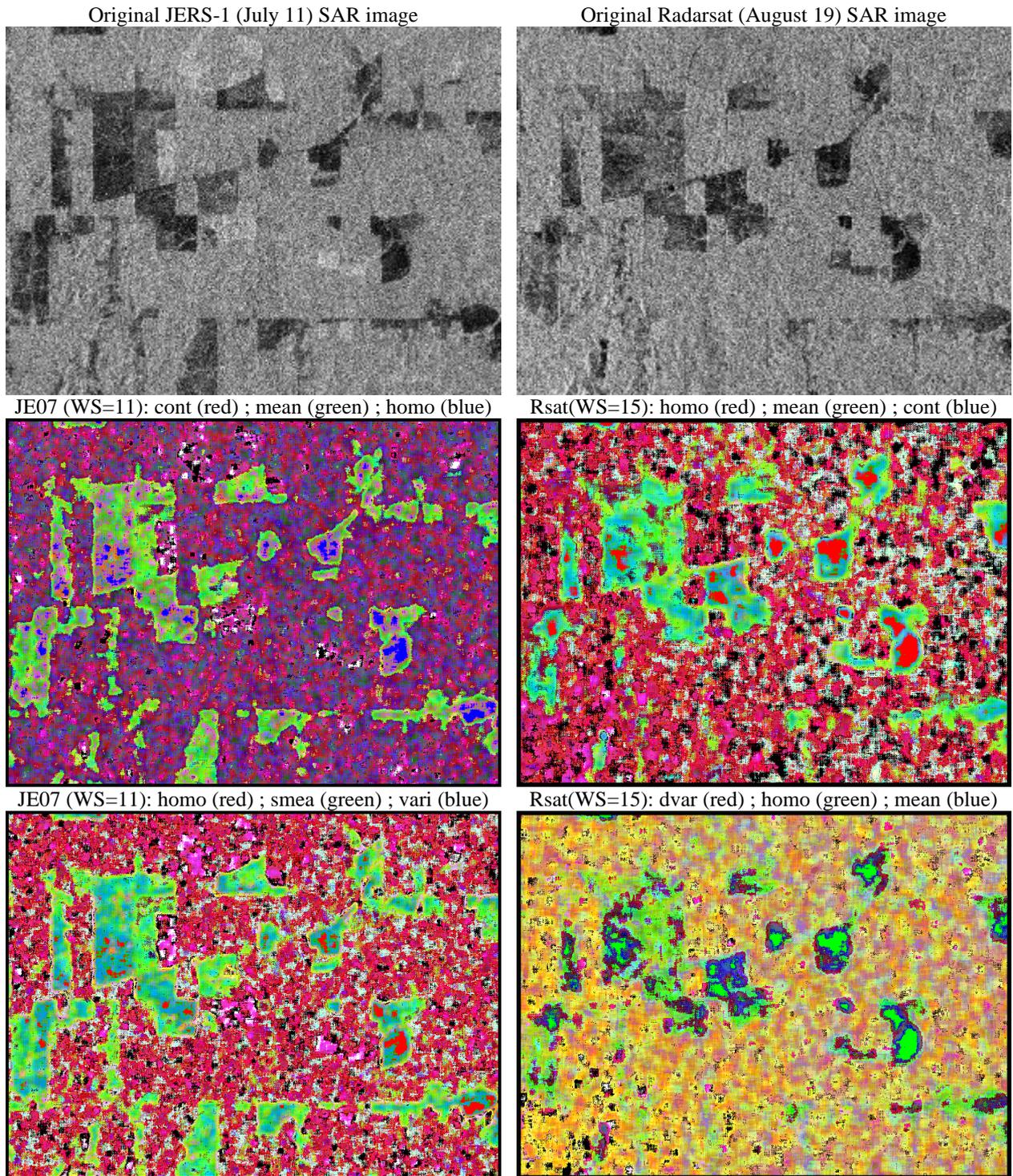


Figure 3: Color composition for original and texture SAR images. Legend: Rsat (Radarsat, August 19) ; JE07 (JERS-1, July 11) ; cont (Contrast) ; mean (Mean) ; homo (Local Homogeneity) ; smea (Mean of Sum Vector) ; vari (Variance) ; dvar (Variance of Difference Vector) ; WS (window size)

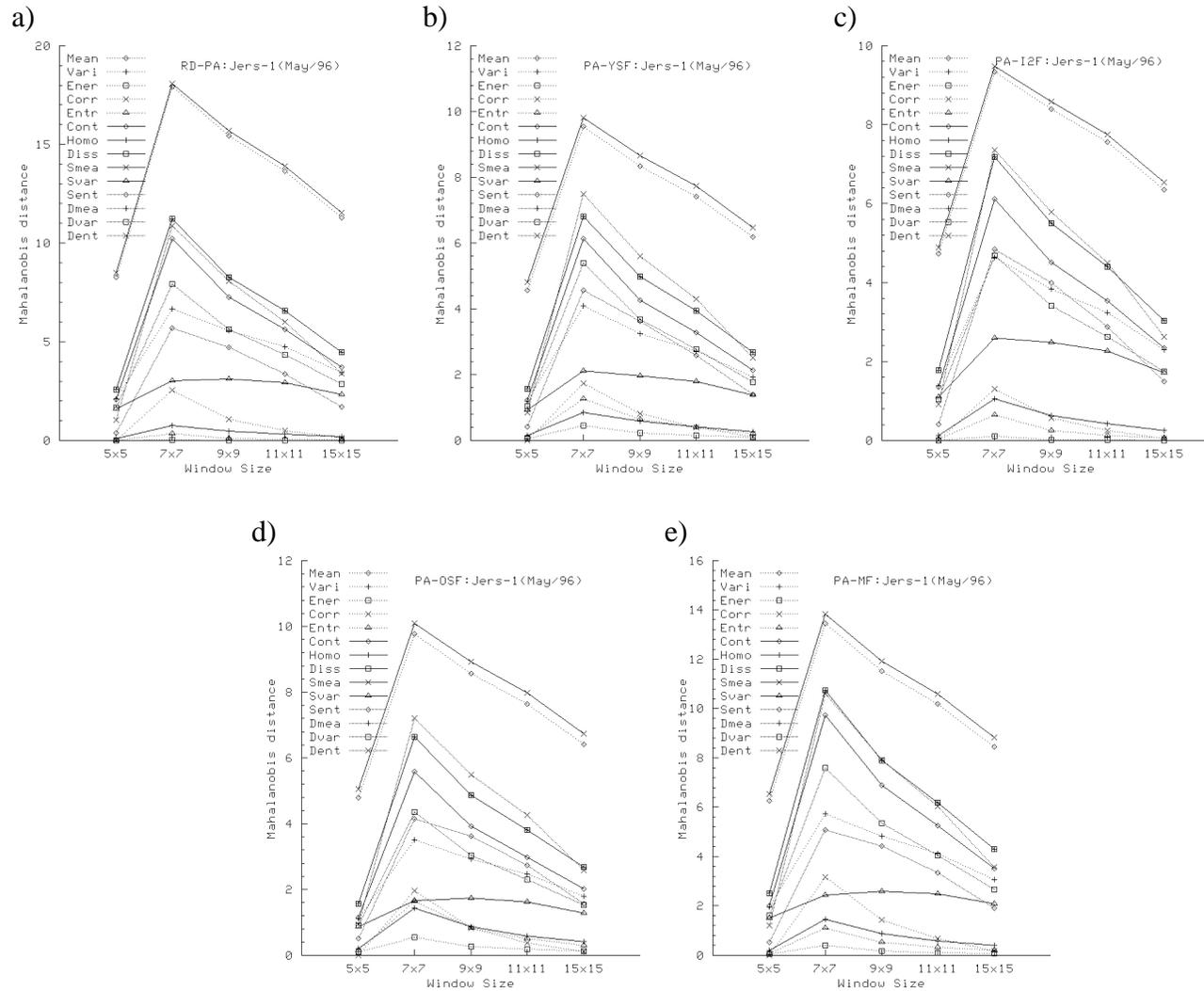


Figure 4: Mahalanobis distances obtained for paired cover classes comparisons, using Haralick's texture measures computed for JERS-1 (May 28, 1996) image. a) RD-PA b) PA-YSF c) PA-ISF d) PA-OSF e) PA-MF

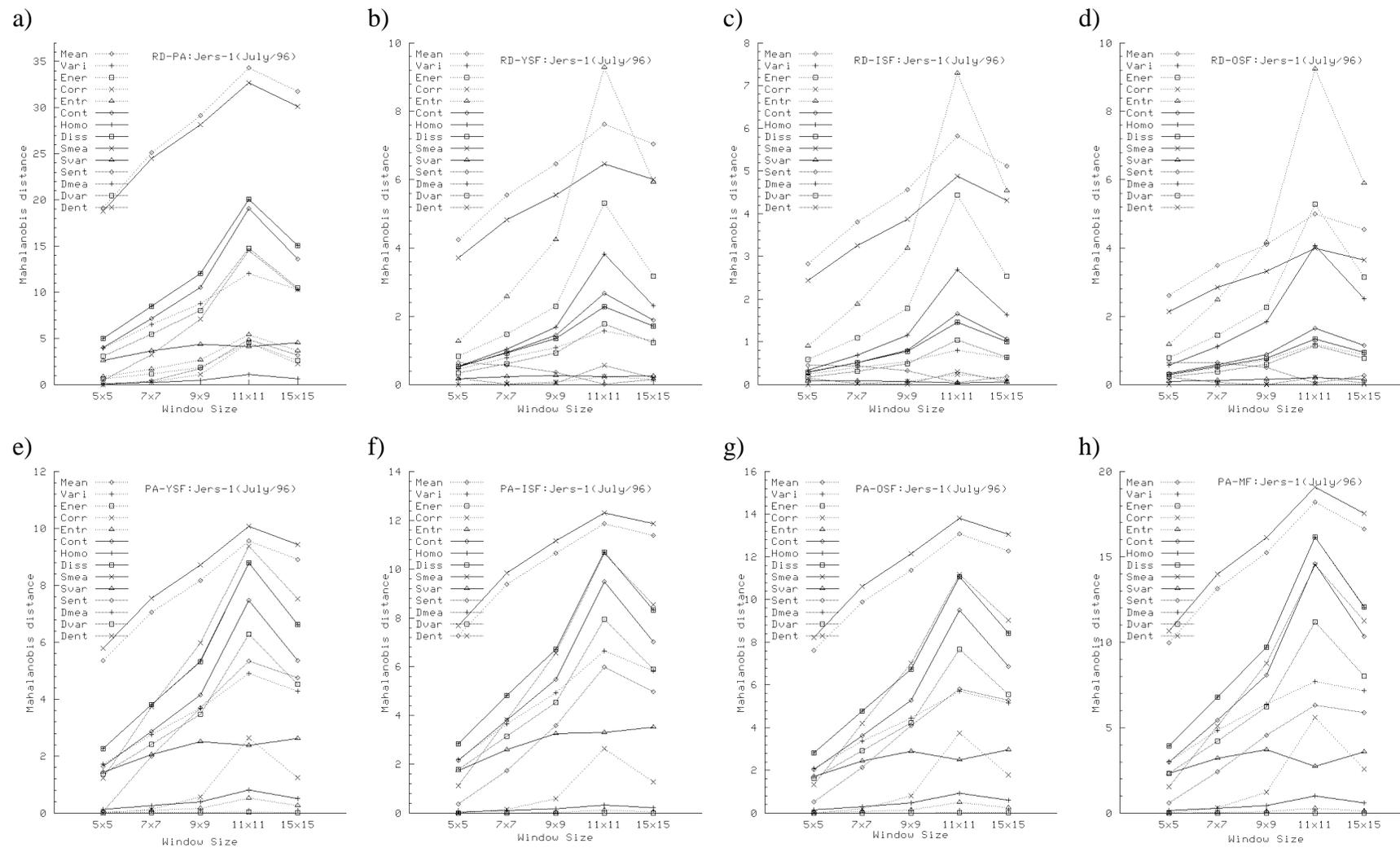


Figure 5: Mahalanobis distances obtained for paired cover classes comparisons, using Haralick's texture measures computed for JERS-1 (July 11, 1996) image. a) RD-PA b) RD-YSF c) RD-ISF d) RD-OSF e) PA-YSF f) PA-ISF g) PA-OSF h) PA-MF

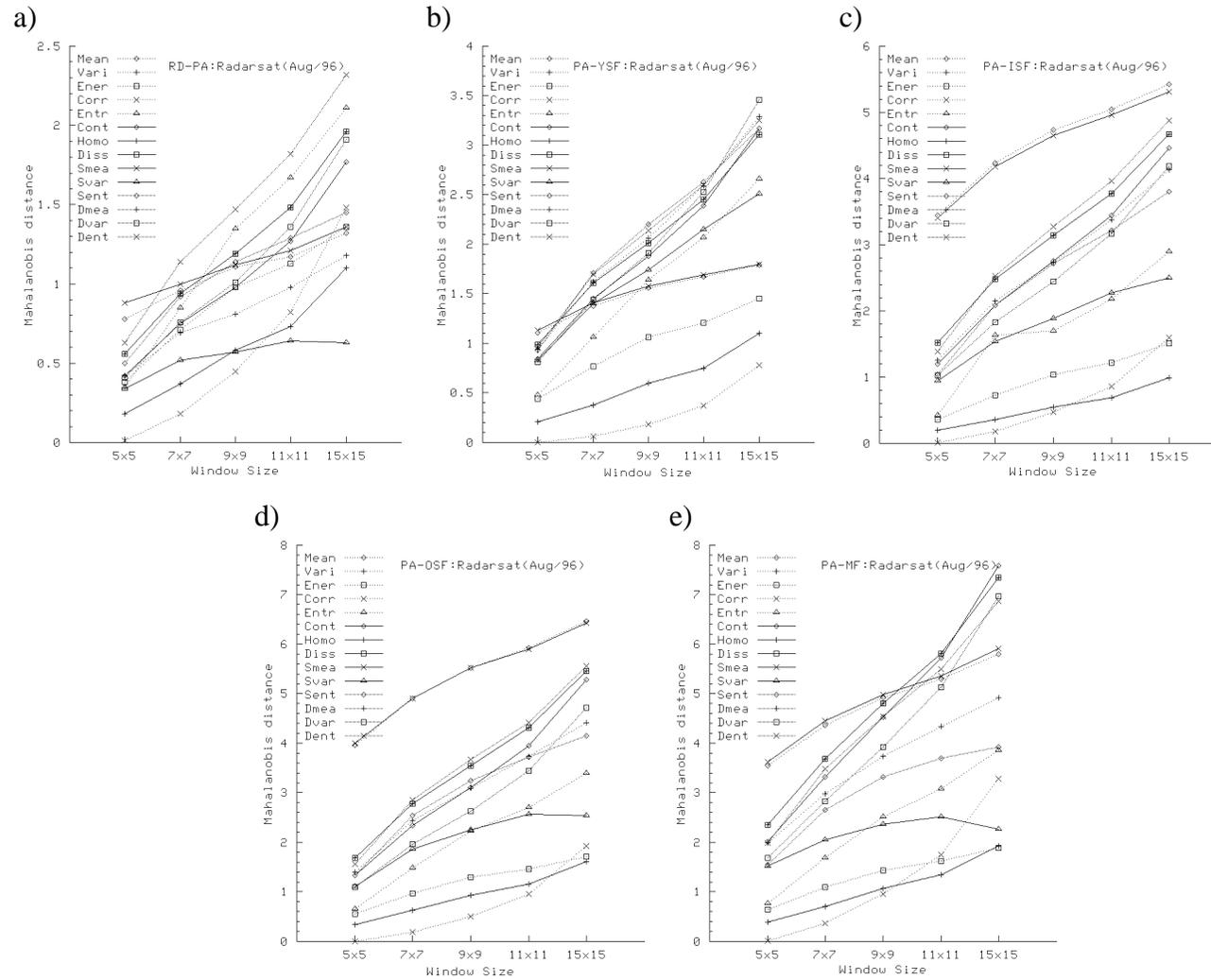


Figure 6: Mahalanobis distances obtained for paired cover classes comparisons, using Haralick's texture measures computed for Radarsat image (August 19, 1996). a) RD-PA b) PA-YSF c) PA-ISF d) PA-OSF e) PA-MF

Observing the Mahalanobis distances for the JERS-1 image collected on May 28 (**Figure 4**), a general tendency of 7x7 window to present the best results can be noticed. Note that windows greater than 7x7 pixels show a decline of their D2 for many of texture measures and paired cover classes. One could also verify that the biggest D2 value was obtained when comparing RD and PA cover classes.

Figure 5 (JERS-1 for July) shows the same behavior observed in **Figure 4**, but in this case the selected window size was 11x11 and not 7x7 pixels. Possibly it may be related to changes in vegetation phenology and associated water content in forest area along the dry season of region.

Comparing **Figure 4** and **Figure 5** for JERS-1 texture images, it can be noticed that, for May, the RD class was only well discriminated from PA and for July it can be noticed a good discrimination between RD and all other cover classes. In fact, when Landsat images for May and July/1996 were checked, it was observed that when JERS-1 image was collected on May 28, some targets appear on clear cut process, with part of their area still covered by MF class. On July 11, all targets selected as belonging to RD class were completely deforested.

Analyzing D2 values for Radarsat imagery (**Figure 6**), one could verify that an ascendant tendency is showed when larger window sizes are used. Unfortunately it is difficult to say, for our study case, what is the best window size for Radarsat because no result for windows greater than 15x15 pixels were computed. Looking at the D2 values for both JERS-1 and Radarsat images, one could find that RD-PA, PA-YSF, PA-ISF, PA-OSF and PA-MF are even better discriminated. In other words, the pasture (PA) class presents a high level of discrimination and if one has interest on this particular class both JERS-1 and Radarsat images could provide good information.

In general terms, the JERS-1 image presented better discrimination between classes when compared to Radarsat. It is interesting to notice that RD and PA were poorly discriminated with Radarsat, but they were the best separable classes in JERS-1 data. Possibly it is related to the band that each sensor operates, where Radarsat (C-HH) is more sensitive to canopy cover, while JERS-1 presents good response to vegetation components such as trunk and stem. For JERS-1 the remaining ground cover just after the clear cut process (unburned slash trunks and stems) could contribute with the best discrimination between RD and PA cover classes.

Conclusions

For the Radarsat image it was noticed that the five herein tested window sizes were still small, denoting that on future studies windows greater than 15x15 pixels should be tested. For texture measures classification purpose, the presented results lead us to choose 7x7 and 11x11 for JERS-1 (May, July) and 15x15 for and Radarsat images.

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