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Suitability of different filters and classifiers for Synthetic Aperture Radar data

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ABSTRACT

The all time and all weather capability of Synthetic Aperture Radar (SAR) make it an attractive tool for natural resource management. A study was conducted to assess the performance of different filters, classifiers and the utility of European Remote sensing Satellite-2 (ERS-2) SAR data for land cover mapping. The study area was Mathura and the surrounding regions of Uttar Pradesh. A number of filters have been developed for radar image speckle reduction, with the aim of eliminating speckle without losing too much of the information contained in the image. There is a trade off between speckle reduction and the preservation of image details. The results achieved depend on the type of filter applied and the window size. Gamma filter with a window size of 5x5 preserved maximum information while suppressing the speckles. Supervised classification of the Gamma filtered image resulted in an overall accuracy of 62% for both Maximum Likelihood and Parallelepiped classifiers.

Key words: Synthetic Aperture Radar, Speckle, Filter and Land cover classification

Introduction

Land is one of the most important natural resources. Comprehensive information on the spatial distinction of land use/land cover categories and pattern of their change is assuming increasing importance in various sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning based on agro-climatic zones. The crop acreage is one of the most important inputs for production forecasts and policy decision on agricultural commodity prices. One of the basic requirements for planning is the availability of timely, accurate and up-to-date information on land use at the shortest time possible. This can be achieved from various satellite based high-resolution remotely sensed data on a cost effective basis.

The land cover classification has traditionally used imagery from the visible/near infrared part of the electromagnetic spectrum (Horgan *et al.*, 1992). But successful data acquisition using optical/near infrared sensors is highly dependent on suitable weather conditions. Radar operating in the microwave window of the electromagnetic spectrum offers a solution to the cloud cover problem, in that radar data acquisition is independent of cloud cover (Bush *et al.*, 1978). More over Radar is an active system making the data acquisition possible at any time.

As far as India is concerned, *Kharif* is the most important agricultural season, but the cloud cover during the season makes the data acquisition in the optical region difficult. More over the foggy conditions during the *Rabi* also create problem for optical remote sensing. Due to its superiority over the optical remote sensing, Radar data can be obtained even in these conditions and could be used for land cover classification. ERS-2, which gives data in C-band, is mainly used for soil moisture studies. In this study we have tried to assess the performance of different filters, classifiers and the utility of SAR data for land cover mapping.

Methodology

The ERS-2 SAR data was acquired over the parts of Mathura on 8th February 1998. The ERS-2 SAR provides data in C-band, VV polarization, 23^0 incidence angle and a nominal spatial resolution of 30 m. The path/row of the scene was 742/192. From this full scene the area corresponding to Survey of India toposheet no. 54E/11 i.e. latitudes $27^015'$ to $27^030'$N and longitudes $77^030'$ to $77^045'$E, was subsetted. Major crops grown were wheat and mustard. At the time of data acquisition, these *Rabi* crops were mostly at flowering stage. The climate of the area is hot semi arid. Length of growing period (LGP) of the region is 90-120 days.

Digital image analysis

Digital image analysis of the data was done using EASI/PACE software. The digital data was converted to backscatter (Mohan *et al.*1995) image using the formula;

$$\sigma^0 = 20 \log DN - 55.11 + 10 \log \sin a$$

Where, σ^0 - backscattering coefficient, a - local incidence angle of radar beam and DN - Digital number.

Image registration

The ERS-2 SAR backscatter data was registered to the Survey of India toposheet by taking ground control points (GCPs) well distributed in the study area and locating them on the imagery. Nearest neighbourhood technique was used for re-sampling so that the originality of the data was retained (Dwivedi and Sreenivas, 1998). A second order polynomial transform was used for the registration, which gave accuracy at sub pixel level.

Speckle suppression

On the image different filters with different window sizes were applied. The filters applied were Gamma, Enhanced Frost, Enhanced Lee, Lee and Kuan. Three different window sizes viz., 3x3, 5x5 and 7x7 pixels were used. The effect of window size on speckle suppression was evaluated visually and for a particular window size the data range was considered to evaluate the performance.

Supervised classification

The training sites were selected for the major land cover categories of the study area viz., water body, scrub, non-saline fields, saline fields, habitat and saline scrub based on ground truth information. The different supervised classification algorithms used were Maximum likelihood, Minimum distance and Parallelepiped. These classifiers were compared for their performance using the overall accuracy.

Results and Discussion

Window size of filters

The speckle noise is an inherent property of the SAR imagery, which is caused by random fluctuations in the signal returned to the antenna from an extended target. To suppress speckle we apply filter to the image. The spatial filtering is done on each individual pixel in an image, using the gray values in a square window surrounding each pixel. The dimensions of the filter must be odd, and must be at least 3 x 3. If the selected window size is too small, then speckle suppression is inadequate. On the other hand, a large window size results in the loss of image detail.

Even though, application of filters of 3x3 pixels window size gave the maximum data range and standard deviation for the image, speckle suppression was found to be inadequate. On application of filters of 7x7 pixels window, the data range and standard deviation for the image was lowest. More over on such images, it was seen that some of the features like drainage channels were getting faded into the surrounding area. This may be due to more reduction in data range resulting in over smoothening. The filters of 5x5 pixels window gave enough speckle suppression and the data range and standard deviation were in between that given by 3x3 and 7x7 pixels window. Hence it was decided to apply a widow size of 5x5 pixels for further image analysis in differentiating the land cover classes.

Effect of different filters on data range

The range of the unfiltered image was -28.11dB to +9.88dB. On application of filters with a window size of 5x5 pixels, the range was reduced to -22.04dB to +9.88dB. The upper range of the data was due to high backscattering from the metallic structures of Mathura refinery and these high values were not affected by filtering, because it was not due to speckles. But the lower data range was due to some stray pixels in the water body and it got altered on application of filters. There was no considerable difference in the range of backscatter values on application of different types of filters except for Kuan filter. The Gamma filter gave the maximum range of -22.04dB to +9.88dB, i.e., the Gamma filter was able to retain the high backscattering features. The result of the analysis is presented in Table 1.But in case of Kuan filter the range was reduced to -22.04dB to +4.33dB, i.e., Kuan filter was not able to retain any high backscattering features.

Supervised classification

Image speckle in SAR data hampers the application of standard pixel-based classification techniques normally used for optical sensor data, hence it is essential to apply some form of image filtering to reduce image speckle (Chakraborty and Panigrahy, 1997), before image classification and the results achieved depend on the type of filter applied and the window size. For supervised classification Gamma filtered (5x5 window) backscatter image was used (Plate 1). Six different land cover categories were identified based on the ground truth survey. These were scrub, habitat, water body, saline scrub, saline fields and non-saline fields. The signatures for these six land cover classes were extracted from the image. Fig. 1 graphically represents the signature mean

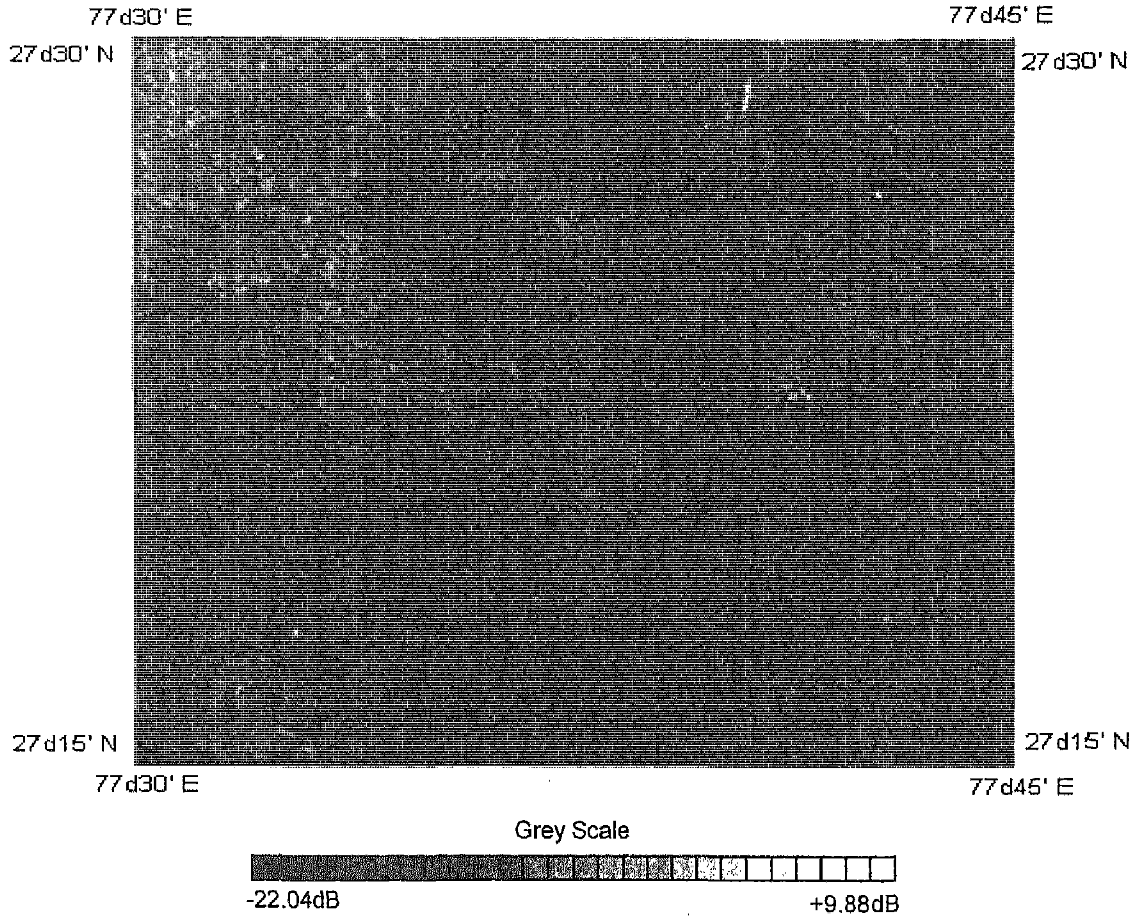


Plate 1. Gamma filtered (5 x 5 window) backscatter image of Mathura region

and standard deviation for the classes extracted from the image, which clearly shows the overlap between the classes. It can be seen that the signatures representing water body, scrub, and good fields are overlapped. The classes comprising saline field, habitat and saline scrub are also overlapped.

Classification

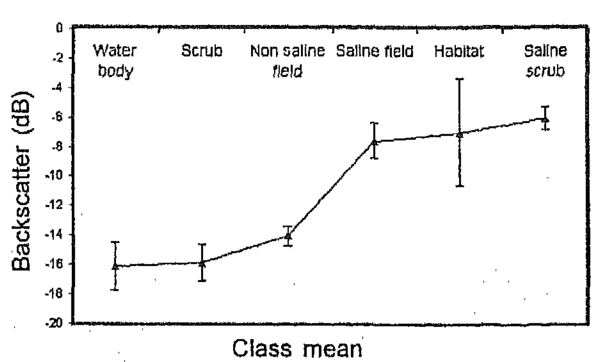


Fig. 1. Comparison of signatures of land cover categories of the area

The Gamma filtered image was used for the supervised classification using different classifiers viz., Maximum likelihood, Minimum distance and Parallelepiped. The confusion matrices for the classifiers are presented in Table 2, 3 & 4. The results showed that Maximum likelihood and Parallelepiped classifier gave an overall accuracy of 62%. But the Minimum distance classifier gave a lower overall accuracy. The Maximum Likelihood classified image is given in Plate 2.

The image was classified using K-Means unsupervised classifier to see how the unsupervised clusters are matching with the land cover signatures. The unsupervised clusters are produced based on the image data statistics and it can be seen from the Fig. 2 that except for saline field there is no matching with the clusters and signatures. This could be due to large internal variability in the signature samples in the SAR data and it may be the reason behind the low overall accuracy by the classifiers.

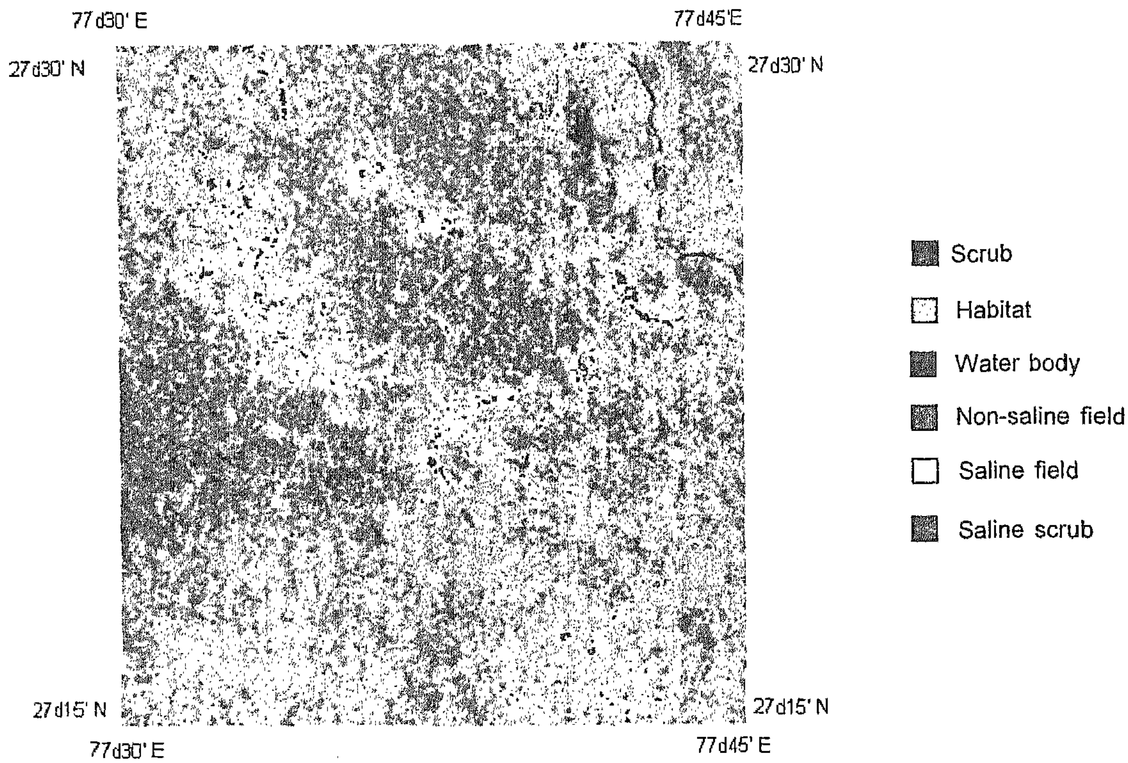
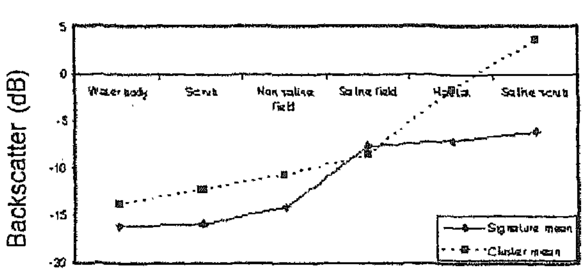


Plate 2. Maximum likelihood classified Image of Mathura Region



Cluster-Signature mean

Fig. 2. Comparison of signature means and cluster means

Table 1. Effect of window size for filtering on data statistics

Filters	Window size	Min. value (dB)	Max. value (dB)	Standard deviation
Gamma	5x5	-22.04	9.88	1.71
Enhanced Frost	5x5	-22.04	8.31	1.70
Enhanced Lee	5x5	-22.04	8.31	1.70
Lee	5x5	-22.04	8.02	1.70
Kuan	5x5	-22.04	4.33	1.70
Average	5x5	22.04	7.77	1.702

Mean for all the filtered and unfiltered image were -11.63

Table 2. Confusion matrix for Minimum Distance classification

Class name	Pixels	Percent pixels classified					
		Scrub	Habitat	Water body	Saline scrub	Saline fields	Non saline field
Scrub	2084	26.15	0.00	46.40	0.00	0.00	27.45
Habitat	2180	0.00	9.63	0.00	35.28	46.06	9.04
Water body	377	25.20	0.00	48.81	0.00	0.00	25.99
Saline scrub	312	0.00	31.13	0.00	66.67	3.21	0.00
Saline fields	642	0.00	20.75	0.00	26.48	52.65	0.16
Non saline field	2692	9.55	0.00	0.41	0.00	0.00	90.04

Overall accuracy = 47.17%

Table 3. Confusion matrix for Parallelepiped classification

Class name	Pixels	Percent pixels classified						
		Null	Scrub	Habitat	Water body	Saline scrub	Saline fields	Non saline field
Scrub	2084	0.00	52.11	0.00	20.78	0.00	0.00	27.11
Habitat	2180	0.96	0.00	43.85	0.00	22.11	33.07	0.00
Water body	377	0.53	51.99	0.00	21.49	0.00	0.00	25.99
Saline scrub	312	0.00	0.00	3.53	0.00	84.94	11.54	0.00
Saline fields	642	0.00	0.00	6.85	0.00	36.45	56.70	0.00
Non saline field	2692	0.00	10.10	0.41	0.00	0.00	0.00	89.49

Overall accuracy = 62.28%

Table 4. Confusion matrix for Maximum Likelihood classification

Class name	Pixels	Percent pixels classified						
		Null	Scrub	Habitat	Water body	Saline scrub	Saline fields	Non saline field
Scrub	2084	0.00	52.11	0.00	20.78	0.00	0.00	27.11
Habitat	2180	1.10	0.00	43.72	0.00	22.11	33.07	0.00
Water body	377	1.06	51.99	0.00	20.95	0.00	0.00	25.99
Saline scrub	312	0.00	0.00	3.53	0.00	84.94	11.54	0.00
Saline fields	642	0.00	0.00	6.85	0.00	36.45	56.70	0.00
Non saline field	2692	0.00	10.10	0.41	0.00	0.00	0.00	89.49

Overall accuracy = 62.22%

Conclusion

The unfiltered data was having lot of specular noises. Gamma filter with a window size of 5x5 was found optimum for the speckle suppression. The supervised classification resulted in an overall accuracy of 62%, which is not a good figure for operational purposes. The class signatures were overlapped resulting in low performance by the classifiers. This may be due to the fact that the data is of single look angle and single polarization. More over the angle of incidence is 23^0, which give the radar beam more penetration through the vegetation resulting in significant contributions from soil.

Depending on the specific methodology used to generate the land cover map, the accuracy levels were found to vary substantially. So a caution is needed when we make comparisons between classification accuracy figures reported by different workers unless their objectives and methodologies are clearly identified (Langford *et al.,* 1997). A low accuracy land cover map still makes a valuable contribution to the knowledge of a little studied environment, provided that its limitations are clearly understood and respected.

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