LAND COVER CLASSIFICATION USING MULTI-SOURCE DATA FUSION OF ENVISAT-ASAR AND IRS P6 LISS-III SATELLITE DATA – A CASE STUDY OVER TROPICAL MOIST DECIDUOUS FORESTED REGIONS OF KARNATAKA, INDIA

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ABSTRACT:

The present study addresses the potential of Synthetic Aperture Radar (SAR) data for land cover classification in parts of Dandeli forested regions, Karnataka, India. a FCC has been generated from coherence and backscattering co-efficient images of ENVISAT-ASAR data (HH polarizations) of 25th Sep 2006 and 30th Oct 2006. Similarly, ENVISAT-ASAR data (HH polarization) of 25th Sep 2006 along with IRS –P6 LISS-III of 11th Jan 2005 were subjected to data fusion to generate a False Colored Composite (FCC) using multi-source Intensity Hue Saturation (IHS) fusion technique. The two FCCs were subjected to maximum-likelihood classification technique separately and classification accuracy from the two methods is computed. Results suggested that SAR data is capable of discriminating major land cover types viz., forests, agriculture, water bodies, barren/fallow, urban settlements. Composition of coherence information given by the ASAR along with backscatter images enhanced the delineation capabilities of SAR data. The over all classification accuracy and kappa coefficient of the False Colored Composite (FCC) were observed to be 78% and 0.75 respectively. Further, an attempt has been made to discriminate different forest types by merging the optical LISS-III data with HH polarized ASAR data. The merged output has been found to better delineate the forest types apart from other land-cover classes and minimize the shadow effect. The overall classification accuracy and kappa coefficient of merged data was observed to be 82% and 0.80 respectively. Results of the study suggest the significance of SAR data towards better classification of the land cover classes, when used in conjunction with optical RS data.

1. INTRODUCTION:

Land cover classification is a primary requirement for management and planning of various resources. Remote sensing techniques aided with ground information provide a reliable source of land cover classification in a cost and time-effective way. While the utility of optical data in land cover classification is well known, the potential utilization of information given by space-borne and airborne RADAR systems in land cover classification is successfully attempted in several studies. Remote sensing using SAR data is useful for mapping and monitoring land cover over tropical regions, where continuous cloud cover hinders optical imagery acquisition. It is important to develop tools to obtain useful thematic information from radar data in terms of landscape features and patterns (Simard *et al.* 2000). RADAR systems are of immense use in deriving forest structural parameters such as timber volume, basal area, dominant height, biomass, etc. at plot and stand-level (Manninen *et al.* 2005).

Radar sensors operating with different wavelengths and polarizations can be widely used for large-scale land cover mapping and monitoring using backscatter coefficients of different polarizations. Further, interferometric coherence derived from complex SAR data provides valuable information, which can be used as an additional tool along with backscatter data to enhance the application potential of microwave remote sensing in discriminating land-cover classes. Apart from this, studies on combining microwave and optical data have also been done in various works, which suggest enhanced discrimination capabilities of merged data and the same can be attempted to yield better classified outputs. Image fusion

techniques deal with integration of complementary and redundant information from multiple images to create a composite image that contains a better description of the scene (Saraf, 1999). Data fusion can reduce the uncertainty associated with the data acquired by different sensors or by same sensor with temporal variation. Further, the fusion techniques may improve interpretation capabilities with respect to subsequent tasks by using complementary information sources (Wen and Chen, 2004).

The fusion of two data sets can be done in order to obtain one single data set with the qualities of both (Saraf, 1999). The low-resolution multispectral satellite imagery can be combined with the higher resolution radar imagery by fusion technique to improve the interpretability of the fused/merged image. The resultant data product has the advantages of high spatial resolution, structural information (from radar image), and spectral resolution (from optical and infrared bands). Thus, the merged image provides faster interpretation (Simone et al., 2002), and can help in extracting more features (Wen and Chen, 2004).Various image fusion techniques are available in published literature (Li et al., 2002; Tu et al., 2001).

In the present study, we attempt to analyze the potential of SAR data in the discrimination of different land-cover classes

2. STUDY AREA:

The study area is in parts of Dandeli sub division, Uttara Kannada district, Western Ghats, Karnataka, India (Fig 1). Geographically it is a transitional zone between the younger rocks of Deccan trap formation and the older crystalline rocks of Archean shield of the Indian Peninsula. The soil on the

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exposed slopes and broad valleys is loamy laterites with pH ranging from 5 to 5.8.

The area experiences southwest monsoon and mean annual rainfall is about 2500mm. The mean monthly temperature ranges from 25 to 33ºC. Native vegetation is evergreen/semi-evergreen type and has a continuum to secondary/moist deciduous types in lower rainfall tracts to the east (Pascal 1986). Champion and Seth (1968) classified the forest on the western slope as tropical evergreen type and included the forest of the eastern zone in the category of South Indian Moist Deciduous type.
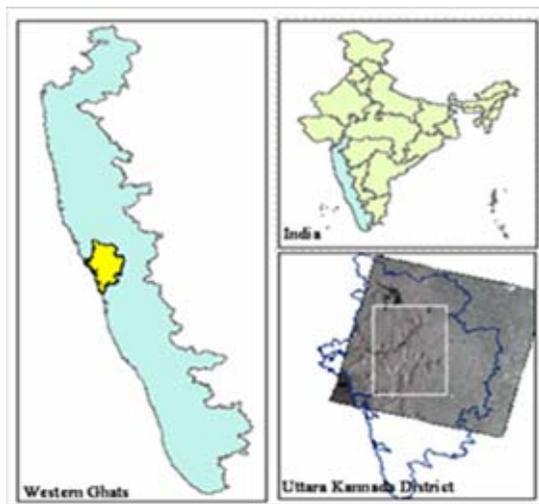

Fig 1: Study area map of Dandeli, Karnataka

3.   DATA DESCRIPTION:

Environment Satellite – Advanced Synthetic Aperture Radar (ENVISAT – ASAR) C-band data of 25 Sep 2006 and 30 Oct 2006 of HH polarizations in IS3 beam position (incidence angle ranges from 26.0º to 31.4º) single look complex images and Indian Remote Sensing Satellite – Linear Imaging Self Scanner-III (IRS-P6 LISS-III) data of 11 Jan 2005 were acquired in the present study for land-cover classification.

4.   METHODOLOGY:

Flow chart of methodology followed in the present study is given in fig 2.

Single Look Complex (SLC) image of the acquired consecutive pairs was processed to generate backscatter coefficient images and then subjected to geo-coding using orbital parameters. The interferometric process of ENVISAT-ASAR data is carried out using the sarmap, application software – 'SARscape' (Francesco and Pasquali, 1998). The baseline between the acquired data set should be low to generate an interferogram and coherence image. The observed baseline in interferometric data set is 173 m, which is well below the critical baseline. Co-registration of the acquired data set is done using SARscape software to use them in the same geometry, by taking SLC-1 as master image and SLC-2 as slave.
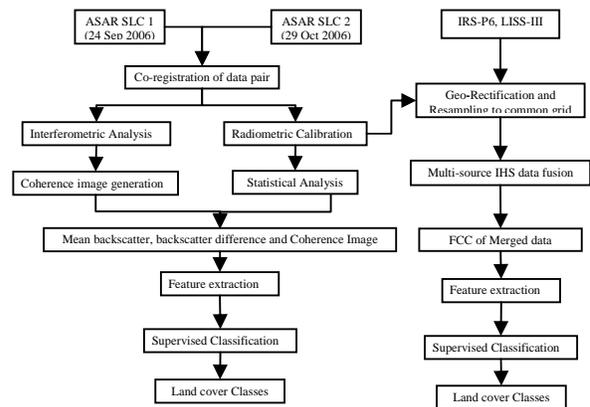

Fig 2: Methodology flow chart

4.1   Processing of ASAR data and coherence image generation:

Coherence between the two images is calculated using the formula

$$\gamma = \frac{|\sum s_1(x).s_2(x)^*|}{\sqrt{\sum |s_1(x)|^2 . \sum |s_2(x)|^2}} \quad (1)$$

where s_1 and s_2 are two complex co-registered images. The window size considered for the coherence image generation is 3X3. The obtained equivalent number of looks (ENL) of the ASAR image for the study area is 1.47.

Power images were generated from SLC images and calibrated to backscatter co-efficient images. Radiometric calibration of the ASAR images is carried out in SARscape software following the radar equation principle, which involves corrections for the scattering area, antenna gain pattern and the range spread loss. Enhanced window size of 7X7 is used for speckle suppression and the data distribution observed is Gaussian. A FCC is then generated using the derived 'mean backscatter' (red), 'backscatter difference' (green) and 'coherence image' (blue).

4.2   Multi-source Fusion of ASAR and LISS-III data:
The ASAR data was geo-referenced to LISS-III data within RMSE of a pixel with desired accuracy. The backscatter images of HH were merged with LISS-III data by Intensity Hue Saturation technique to generate a composite image for better discrimination. As IHS technique is considered as standard procedure in image analysis, this technique was used for fusion in the present study. The IHS is a colour related technique which effectively separates spatial (*I*) and spectral (*H*, *S*) information from a standard RGB image.

The (i) FCC generated from coherence and backscatter coefficients of HH images (Fig 3) along with (ii) merged data (Fig 5) were subjected to supervised classification using maximum likelihood classifier, by giving training areas based on ground based information and literature to delineate the land cover classes of the study area and to analyze land cover discrimination capability of the SAR sensors. Accuracy

assessment of the classified outputs has been carried out and confusion matrices have been derived.

5.   RESULTS AND DISCUSSIONS:

5.1   Coherence based analysis:

Results suggested that SAR data is capable of discriminating major land cover types viz., forests, agriculture, water bodies, barren/fallow, urban settlements. Composition of coherence information given by the ASAR along with backscatter images enhanced the delineation capabilities of SAR data (Fig 3).
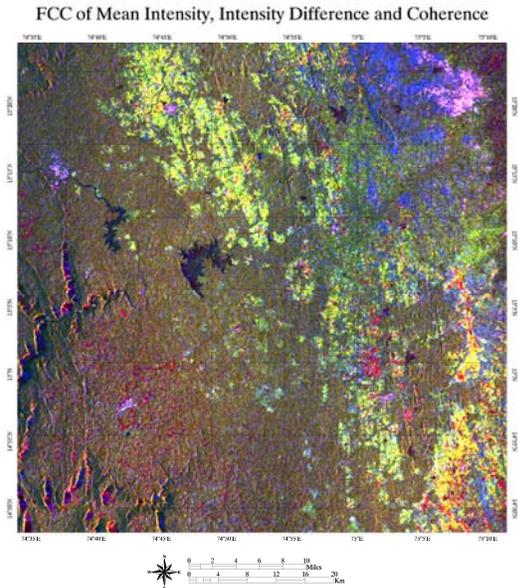
FCC of Mean Intensity, Intensity Difference and Coherence

Fig 3: FCC of mean intensity (Red), intensity difference (Green) and coherence image (Blue)

It is observed that the inclusion of coherence band along with the backscatter coefficients in HH polarization has enhanced the delineation capability compared to stand alone HH backscatter values. The discrimination of Forest, Agriculture, Water, barren/fallow and urban settlements is distinctly observed (Fig 4). Coherence is a function of systemic spatial decorrelation, the additive noise, and the scene decorrelation that takes place between the two acquisitions. It is observed from the coherence image, that the average value of coherence in the study area was very low (<0.5) as the majority area is covered by vegetation. This can be attributed to the wind patterns in the study area that might alter the orientation of scattering objects (leaves, secondary branches) in the vegetation layer. Highest coherence values were observed in barren areas followed by agricultural areas over the study areas, which are in accordance with the results reported in earlier studies (Wegmuller and Werner 1997), which suggested urban areas, agricultural areas, bushes and forests have different correlation characteristics, with urban areas showing the highest correlation and forest the lowest. Medium coherence and high backscatter difference values were observed for the agriculture areas. As the temporal gap between the two images acquired is 35 days, agriculture areas showed some difference during the two acquisitions. It is observed that both the coherence and backscatter difference values of the forested areas as low compared to other land cover types. This is attributed to the

temporal decorrelation effect that occurs on longer time scales like the growth of the vegetation, man made changes, fires etc (Strozzi *et al., 2000)*. The over all classification accuracy and kappa coefficient of the False Colored Composite (FCC) were observed to be 78% and 0.75 respectively. Urban settlements and barren areas were clearly discriminated in the False Colored Composite (FCC).
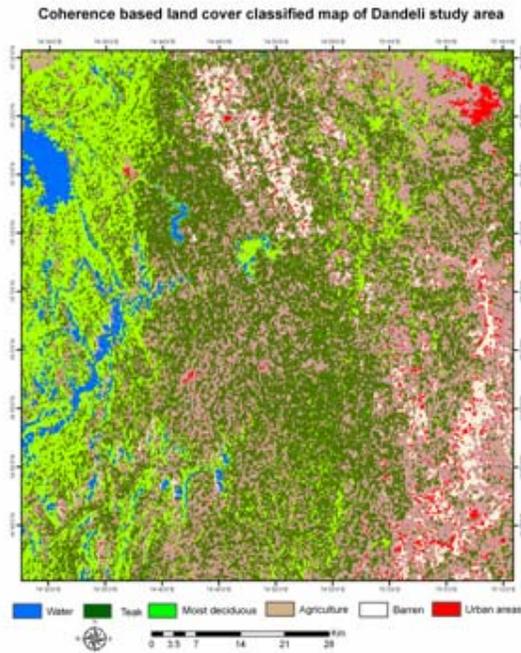
Coherence based land cover classified map of Dandeli study area

Fig 4: Vegetation type classified map generated from FCC of mean intensity, intensity difference and coherence image

However, it was observed that in some areas the shadow areas were misclassified as water bodies and steep terrain areas with high backscatter values have some overlap with urban settlements in the False Colored Composite (FCC). Though there was a clear distinction between vegetation and non-vegetation, the discrimination within the forest types was observed to be less clear in the False Colored Composite (FCC). So, an attempt has been made to discriminate different forest types by merging the optical LISS-III data with HH polarized ASAR data.

5.2   Multi-sensor Fusion analysis:

The merged output has been found to better delineate the forest types (Fig 6) apart from other land-cover classes and minimize the shadow effect. The IHS refers to the transformation of three image channels assigned to I, H and S (Rast *et al.* 1991). The second transforms three channels of the data set representing RGB into the IHS colour space which separates the colour aspects in its average brightness (intensity). This corresponds to the surface roughness, its dominant wavelength contribution (hue) and its purity (saturation) (Carper *et al.* 1990). Both the hue and the saturation in this case are related to the surface reflectivity or composition. Then, one of the components is replaced by a fourth image channel which is to be integrated.

The classification accuracy of remote sensing images was improved when fused data was introduced to the processing. ASAR images contributed different signals due to differences in surface roughness, shape and moisture content of the observed ground cover. And the optical data rely on the spectral signature of the ground targets in the image. Therefore, fusion of optical and microwave data provided a unique combination that enhanced the identification of targets, forest classification as compared to the results obtained with the ENVISAT-ASAR data.
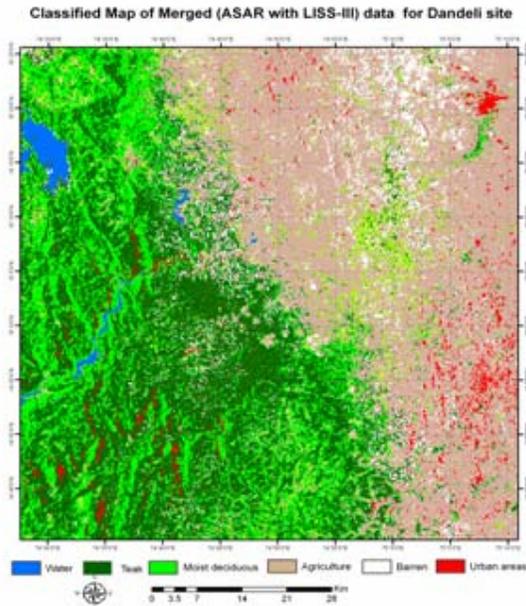
Classified Map of Merged (ASAR with LISS-III) data for Dandeli site

Fig 6: Vegetation classified map of IHS merged data
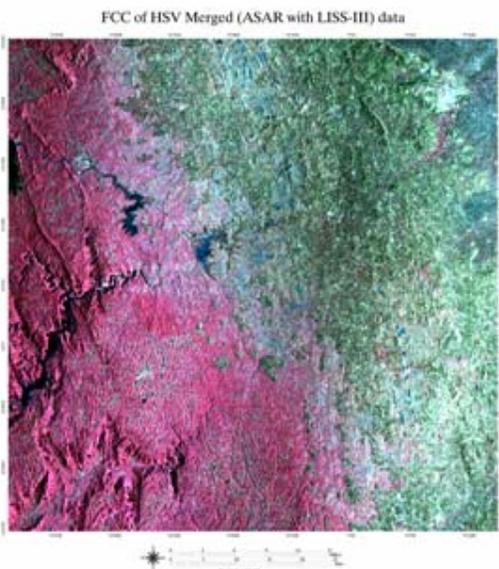
FCC of HSV Merged (ASAR with LISS-III) data

Fig 5: FCC of IHS merged (ASAR with LISS-III) data

The overall classification accuracy and kappa coefficient of merged data are observed as 82% and 0.80 respectively. Fused data provided robust operational performance, i.e., increased confidence, reduced ambiguity, improved reliability and improved classification (Rogers and Wood 1990).

Fused image enhanced the classification capability within the forests. Teak forests were clearly discriminated in the fused image. There was clear distinction between forested and agricultural areas in the merged image.

6.   CONCLUSIONS:

The analysis and results of the present study emphasize the potentials of SAR data in discriminating different land cover types in the tropical regions like India. SAR data can contribute significantly towards better classification of the land cover classes both standalone and when used in conjunction with optical RS data. However, the constraints in the classification techniques by ASAR when used exclusively with respect to forested areas can be overcome with the use of use of multi-frequency and polarimetric data.

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