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PHYSICAL SCATTERING MECHANISM OF SYNTHESIS APERTURE RADAR (RADAR SAT-2) BY USING POLARIMETRIC ANALYSIS METHOD TO IDENTIFY WATER BODIES OVER EARTH SURFACE

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Abstract

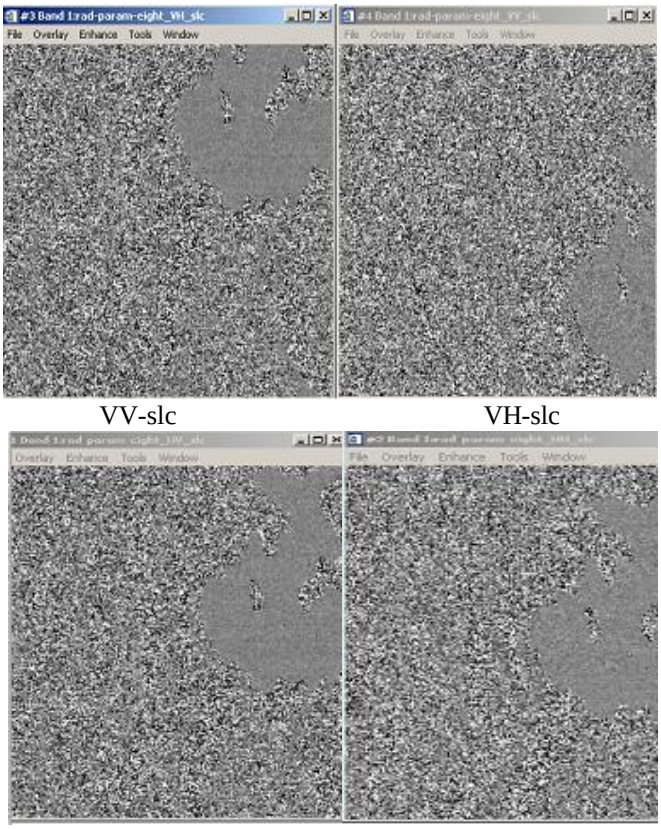
Synthetic Aperture Radar (SAR) is one of the active microwave sensor that can capture the Electromagnetic Radiation signals of the physical objects. The ability of the microwave sensor to work in day and night is one of the major advantages and very useful in this technique. The capturing of scattered signals from SAR by using polarimetric process is applied to analyze distribution of various object types in the South Parambikulam region of Kerala. The study area contains water bodies, forest, vegetation and soil cover. There are many type of scattering methods available for SAR applications, those are multiple scattering, volume scattering, double bounces scattering and surface scattering. Depends on the scattering nature, it is possible to interpret the different types of object bodies. The SAR image used in this paper has taken from the RADARSAT-2 satellite.

Introduction

The Fully Polarimetric – SAR (RADAR SAT-2) sensors are becoming more important in Remote Senescing applications due to its sensitivity of the polarization state of the back scattered wave to physical characteristics of the ground target (e.g. Shape, Size, Orientation, Surface Roughness, moisture, content dielectric properties of the target); (Wood House, 2006; Tso and Mather, 2001; Brunzzone el, 2004). The utilization of multi–polarized wave image polarimetric–SAR system allows to extract additional information, which can be employed as a classification features, thus giving better land use and land cover classifications results compare to single–channel single polarization SAR data (Karathanassi and Dabboor , 2004; Wood house, 2006). Many algorithms have been proposed for supervised and unsupervised classification of polarimetric – SAR data. In supervised classification approach, the choice of training areas which adequately represents the spectral characteristics of each class is important as the quality of training set has a profound effect on validity of results. The SAR technology, due to its high spatial resolution and soil penetration capability, is good choice to identify possible catastrophic failure. The Radar backscatter data is capable of identifying variation in soil properties of the area.

Data and Methodology

RADR-Sat - 2, data will gives raw diagrams of SAR images in the form of Single look complex data images (VV,VH, HV, HH) Figure 1**.**

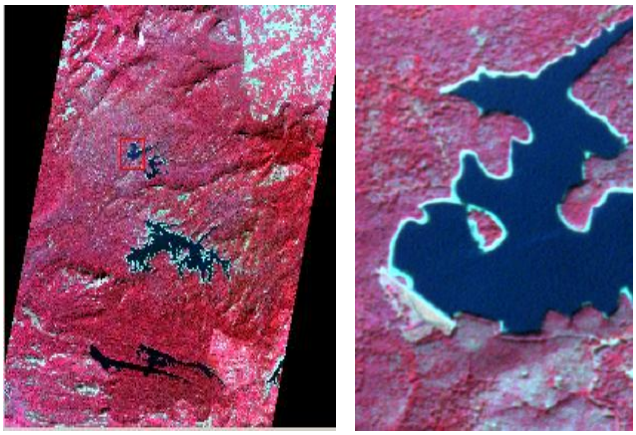


VV-slc VH-slc

HV-slc HH-slc

Figure Synthetic Aperture data: RADAR SAT-2, Synthesis Aperture Radar (SAR) produces Raw single look complex (SLC) image at Radarsat – 2 quadppol (HH, HV, VV, VH);

There is four combinations of transmit receives polarization: HH-horizontal transmit and horizontal receive, VV-Vertical transmit and vertical receive, HV-Horizontal transmit and vertical receive. VH-Vertical transmits and horizontal receive.



A B

Figure 2. The comparison between single look complex data A image and the LISS IV B optical image.

Because of we have to bring given complex data images in the form of clear images as Optical image by using polarimetric method. SAR image having so much of sparkle (Composite of dark and bright fringes-noise), those does not give clear idea of imaged. Sparkles act as a mask for image (Figure 1). Frost filter to gamma filtering, the image will be Produced from the clear up to all sparkles. The ENVI 4.1 software is used for, the process of polarimetric method included in the software. The SLC (Single Look Complex data) data image files used as input files for the soft ware. SAR scaped is advanced for the image processing techniques. The polarimetry and POLSAR tool was used for the processing of polarimetreic to get clear image. The steps for polarimetric methods are; Polarimetric signatures, Polarimetric synthesis, polarimetric features, Polarimetric decomposition, Polarimetric Entropy and Anisotropy, Alpha, Decomposition, and Polarimeteric Entropy, Anisotropy, Alfa classification.

Algorithm

The algorithm indicates, what the steps are, we have to follow for the retrieval of real useful image, which has been helpful to identification of natural resources in study area**.**

The SAR-RADARSAT-2 produced a single look complex (SLC) image. The image produced by the SAR was produced by different methods of horizontal-horizontal, horizontal-vertical, vertical-vertical, Vertical-Horizontal. (hh,hv,vv,vh); The sparkles are removed by the different methods those includes; Frost filter, Lee Filter and Gamma Filter. These methods are used for removal the unwanted things in the image due to interpretation. Removal of nothing but filtering of the image is one of the major method in image processing techniques.

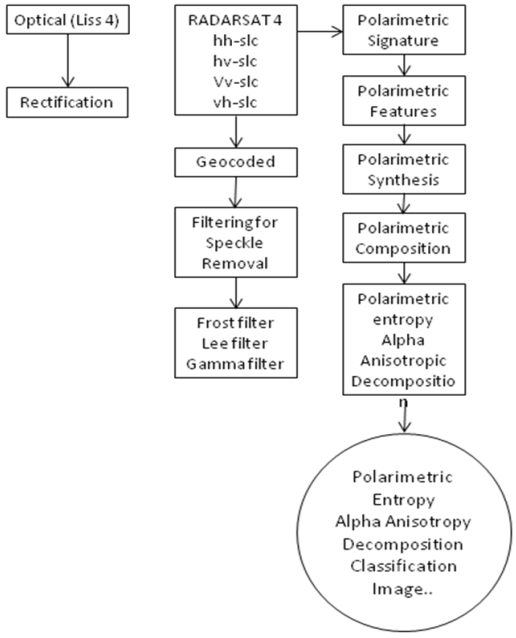


Figure 3. Algorithm in development of image through polarimetric method

The polarimetric method is one the image processing method for understanding the natural resources in the study period. The relation between the three physical parameters will explain in the image at different signature. Classification of image is one of the major and final steps in understanding the image. The polarimetric signature provides the real and theoretical estimates of the co-polarized and cross polarized signature of point target like (Corner reflector). The residual polarimetric calibration errors are also estimated. In the polarization synthesis, the data set was linearly polarized; it can create the (Synthesize) scattering matrix for any arbitrary polarizes orthogonal basics. Polarimetric decomposition provides coherent (i.e. Pauli Decomposition) and incoherent (i.e. Entrophy and Alpha-Anisotropy eigen decomposition) methods for the scattering matrix decomposition. The coherent method suitable for coherent local targets characterization and incoherent methods intended for distributed target characterization.

The Synthesis RADAR, polarimetric method is unsupervised classification method and it can discriminate different scattering behaviour on the basic of the Entropy–Alpha Anisotropy Decomposition result.

The major features and advantages of the polarimetric analysis image processing techniques

It provides some possible combination of raw data (c) and cross-polarized polarimetric intensity data, which can be suitable for further interpretation or classification purpose. Polarimetric signature is a plot of the backscattered power received from specific scattered as a function of the polarizations of the incident and scattered electromagnetic wave. The polarization is described by the four independent variable, the elliptically and orientation of the incident wave, an elliptically and orientation of the backscattered wave. The measurements of the scattering matrix S corresponding to a complex coherent target are nothing but polarimetric decomposition. The physical properties of the scatters are extracted and interpreted through the analysis of elementary responses S_i and corresponding coefficients C_i.

Co-planarization signature and cross polarization signature are major classifications for the polarization signature methods**.** The cross polarization signatures have "A 3- dimensional plot showing the backscattered power as a function of the orientation and ellipticity of the EM wave, when the incident and backscattered polarization are same. If the signature has a single peak centered at ellipticity is = 0 and orientation = 90° the received power is maximum, when the polarization are linear vertical. Cross polarization will occur, when all A 3- dimensional plot showing the backscattered power as a function of the orientation and ellipticity of the EM wave, when the incident wave orientation varies from 0° to 180° degrees, and its ellipticity varies from -45^0 and $+45^0$, in cross polarization case, the backscattered polarizations are orthogonal to the incident polarization.

The polarization synthesis can be performed by converting the scattering matrix to the stokes matrix, then pre-multiplying and post-multiplying the matrix by the unit Stokes vector representing the desired polarizations of the receive and transmit antennas respectively nothing but polarimetric synthesis. One common use of polarization synthesis is to construct the polarization signatures for a selected class of targets, and use these geometric representations to help interpret the scattering mechanisms present in a scene. The four measurements (HH, VV,VH and HV) permit the calculation of the power received from a resolution cell of transmitting and receiving polarization. Three methods are typically employed to characterize coherent scatterers based on the scattering matrix *S*; The Pauli, Cameron and Krogager decompositions are major decomposition methods for analysis of Decomposition. This function provides the decomposition results coming from the Pauli method. Three single channels and their color composite (namely, _k2_slc, _k3_slc and _k1_slc respectively assigned to the Red, Green and Blue colors) are generated. The Even-bounce (HH-VV)**,**-Dihedral rotated 45^0 (HV+VH), - Odd-bounce (HH+VV) are major scattering mechanisms.

Mathematical Background

There are many mathematical formula have been used for getting clear SAR image. But in this paper two basic mathematical formula have used for bringing raw SLC image and the mathematical theory have been used for image processing techniques for SAR image to compare the optical data sets. Radasat-2 was developed by Defense R&D Canada – Ottawa Technical Memorandum DRDC Ottawa TM 2007-189; It is acquiring repeat track SAR data. It provides differential interferometer measurements to estimate surface deformation. The key parameters of the RADARSAT 2 instrument are given in the table.

Table 1. The key parameters of RADARSAT 2 instrument

Parameter	Value
Frequency	C-band (4000 - 8000Mhz)
Wave length	7.5 to 3.75cm
Range resolution	3-100m
Number of looks	4
Polarization	single poll, dual poll, full poll
Range swath	50 - 500km
Look Angle	20-49°
Altitude range (Km)	798
Repeat cycle	24 days

Table -2 Different modes of RADARSAT 2.

Parameter	Standard mode (meters)	Fine mode (meters)
Azimuth Sample Spacing	5.1 m	
Azimuth Resolution	8 m	
Slat Range Sample Spacing	11.8 m	4.7 m
Slat Range Resolution	12.7 m	5.0 m
Incident Angle	20°-49°	20°-49°

To identify the land surface features in the region of Parambikulam area of Kerela, we used interferogram . Cloud and pottier developed a polarimetric decomposition theorem based on the eigen vector analysis of the coherency matrix calculated for each pixel and it is used to retrieve three important parameters; Entropy (H), Scattering Angle (α), and Anisotropy (A), by interpreting the analysis as a measure of entropy, and scattering angle, the classification of the scene can be made into nine scattering zones; (Lee et.. al, 2000) derived at a distance measured based on complex wishort distribution between a coherency matrix and a cluster mean of class for multi look polarimetric of SAR data. The unsupervised wishart classification proposed by them is based on the cloue-pottier H/alpha classification. Freeman and Durden developed unsupervised classification algorithm, which provide information on the Terri scatter type. The algorithm separates the image into three classes; surface, double bounce and volume scattering classes. These

backscattering properties of the target are described by a scattering matrix S which represents the reflectivity of the area being observed at a given radar wavelength.

$$\text{Scattering Matrix } S = \begin{pmatrix} S_{hh} & S_{hv} \\ S_{hh} & S_{hv} \end{pmatrix}$$

Hermitian matrix; The coherency matrix is 3X3 hermition matrix generated by the outer product of K_p with its convector with its conjugate transpose and is given by

$$\text{Coherency matrix } [T] = K_p . K_p T$$

$$\text{Scattering matrix } K_p = \frac{1}{\sqrt{2}} \begin{pmatrix} S_{hh} + S_{vv} \\ S_{hh} - S_{vv} \\ 2\, S_{hv} \end{pmatrix}$$

($S_{hv} = S_{vh}$ due to symmetry)

Where **X** and T represents, the complex conjugate and transpose respectively.

The three diagonal elements of the coherency matrix correspond to surface, double bounce and volume scattering components of the data. The decomposition parameters Entropy (H), Alpha (α), and Anisotropy (A), are extracted from the coherency matrix. The parameter Entropy (H) indicates the degree of randomness of the scattering medium. The Anisotropy parameter is to discriminate scattering mechanisms with different Eigen values distribution and the parameter (α), is an indicator of dominant scattering mechanism .These parameters are defined as

$$\text{Entropy } H = -\sum_{i=1}^{3} p_i \log 3 (p_i)$$

$$\text{Where } P_i = \frac{\lambda_i}{\Sigma \lambda_k} \quad \text{where k =1}$$

Where p corresponds to the pseudo-probabilities obtained from the Eigen values λ, the anisotropy parameter measure the importance of the second and the third Eigen values of the eigen decomposition and is given by:

$$\text{Anisotropy } A = \frac{\lambda_1 - \lambda_2}{\lambda_2 + \lambda_3}$$

The parameter alpha is an indicator of scattering mechanism, which ranges from 0 to 90˚

$$\text{Alpha } \alpha = \sum_{i=1}^{3} (p_i \text{ (alpha i)}$$

Claude and Pottier proposed an algorithm to identify in an unsupervised was polarimetric scattering mechanisms in the H- α (Entropy-Mean alpha angle) plane. The basic idea is that entropy arises as a natural measure of the inherent reversibility of the scattering data and that the mean alpha angle can be used to identify the underlying average scattering mechanism

Study area and data used

The study area Parambikulam is situated between longitude 76°35'-76°50'E and latitude 10°20'-10°26'N, comp-

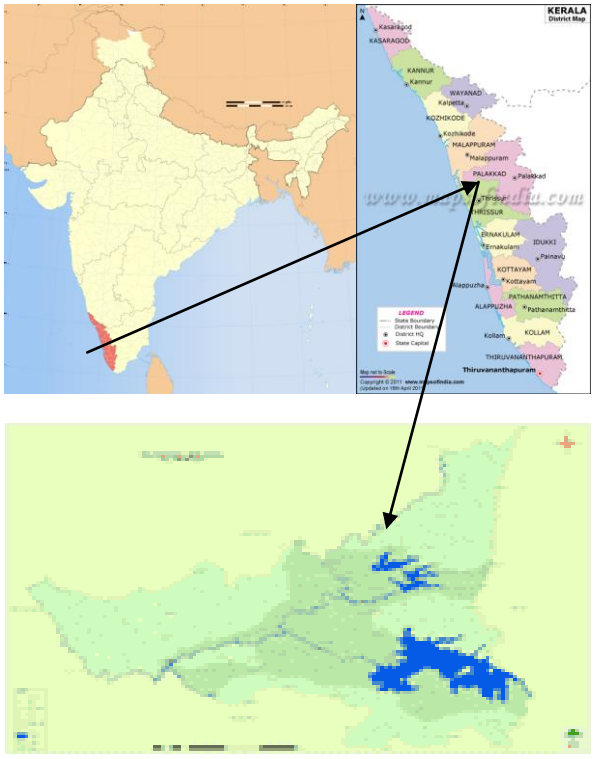


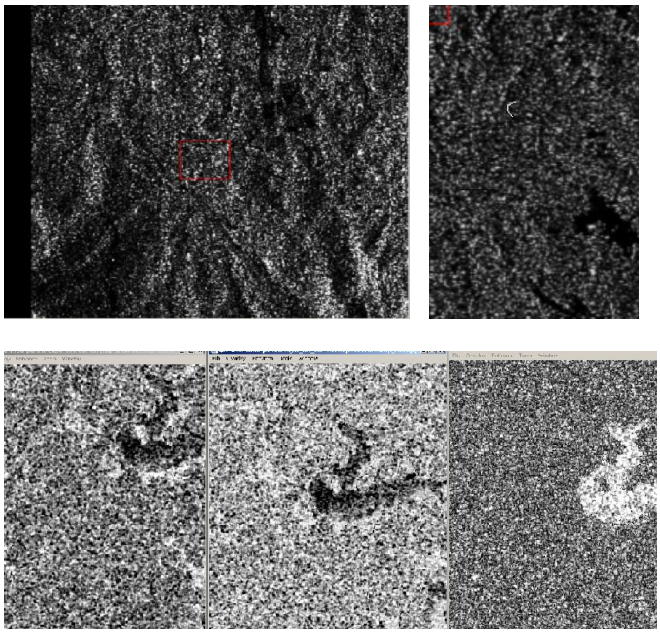
Figure 4. Study area of Parambikulam in Kerala, India

osed of 285sq.km, in district of Palakkad, Kerala. The north of the study area is covered by Normada forest division, in the south Vazhachal forest division and in west area is having Chalakudy forest division, the east of the study area state of Tamilnadu is located.

The study area contains information regarding land, water bodies, forest and vegetation. We are interested to highlight the presence of natural resources. The results of identification of natural resources compared with the optical images. We used two fully polarimetric RADARSAT-2 level 1.1 Single Look Complex (SLC) satellite data with amplitude and phase of the south Parambikulam area.

Results and Discussion

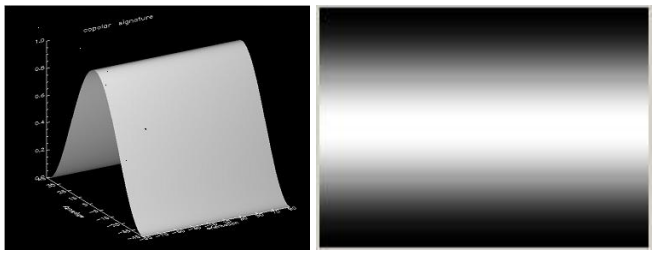
The Polarimetric decomposition was used to illustrate the extra information content of the polarimetric data. Figure 5 shows that the Entropy (H), anisotropy (A), and Alpha- angle for this data. The fist image shows that the land, while forest is highlighted in the central image smooth water shows the lowest entropy due to homogenous scattering,



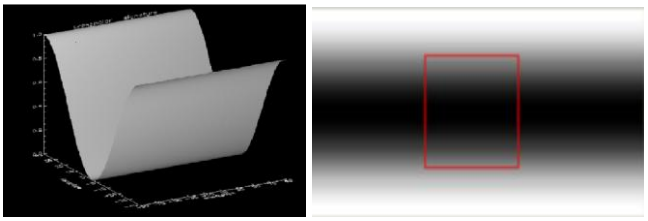
Alpha (α) Entropy (H) Anisotropy (A)

Figure 5. Illustration of the Entropy (H), anisotropy (A), and Alpha- angle for this data.

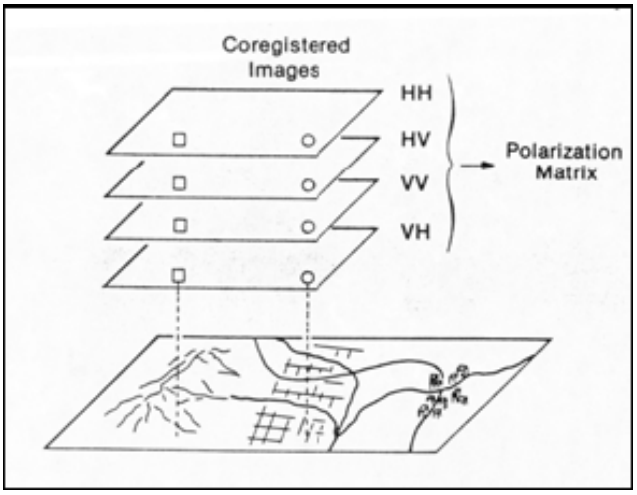
whereas forest has higher entropy. The anisotropy is lower for forest and higher for water providing the best contract for forest/water. The Alpha angle is low for smooth water, which along with low entropy demonstrates surface scattering dominates, where the surface scattering represented in blue, double –bounce scattering is set to red and volume scattering is set to green, according to three coefficients the dominants scattering can be determined and It S_i is observed next unsupervised H/alpha classification is performed based on the polar metric target decomposition parameters. Entrophy (H) and scattering angle (α), which are derived



a



b



c

Figure 6. a) Indicates the How the co-polarization will exists and produced image due to co-polarization. b). Indicates the cross polarization and its produced image for above. c) Indicates the how Polarimetric synthesis will occur in for the SLC image. HH, HV, VV, VH methods shows what are the steps will follow the synthesize the real image.

from the eigen value decomposition of coherency matrix. The α angle corresponds to the variation in scattering mechanism with $\alpha = 0$ corresponds to the surface scattering, $\alpha = 45°$ corresponding to dipole scattering and $\alpha = 90°$ double bounce scattering for smooth surface scattering dominates and entropy is close to 0. The randomness of scattering characteristics in the forest area cause high entropy in the abuse of river cause low entropy due to the its surface (Isotropic) scattering.

All the pixels in the image were classified into nine zones on the H/Alpha plane. Forest areas is dominated by volume scattering, while water areas mainly characterized by surface scattering. Surface scattering is still dominated for bare soil, but a significant amount of double bounce

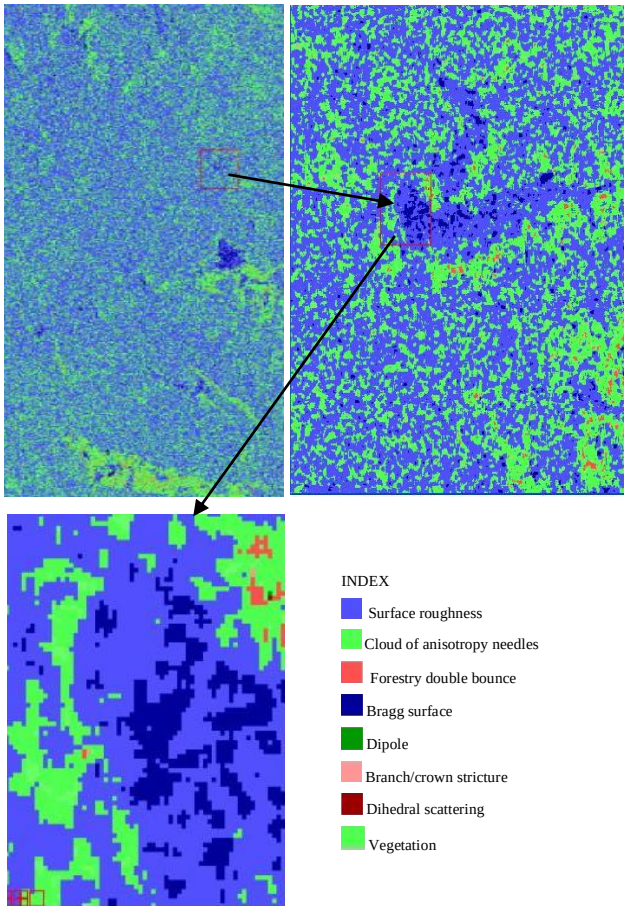


Figure 7. The classification results, It can be observed that water and bare soil are dominated by the surface scattering with blue color.

scattering is present. This indicates that a number of the fallen tree trunks and branches lying on the clear-cut areas may cause double bounce scattering is present. This indicates that the no. of fallen trees trunks and branches lying on the clear-cut areas may cause double –bounce scattering.

For surface scattering HV is small, HH and VV correlated and their phase is close to the o degrees. Science the RADARSAT-2 S L-band instrument has a relatively long wavelength, it penetrates through short vegetation and the backscattered is mostly from the underlying ground. Forest areas produces volume scattering (green color) with small amount of double –bounce scattering (red color). For volume scattering HV is large HH and VV is weakly correlated. Double bounce scattering dominates in case of young trees where there is strong backscattered from the leave and trunks.

Based on the Freeman - Durden decomposition Polar metric classification according to scattering mechanism may provide additional useful information regarding target characteristics within area. Figure 7 shows a simple classification of the forest area. It classifies the dominant scattering behavior of each pixel into one of four scattering classes: 1. Multiple scattering; 2. Volume scattering; 3. Surface scattering and 4. Odd bounce scattering, even bounce scattering or diffuse scattering. The classification results show that forest with in the area is predominantly double bounce scattering (multiple scattering). It is appear red colour. Surface scattering is mainly dominant by bare soil. It appear on the image is blue colour. Characteristic of a smooth to slightly rough surface, water areas are predominantly characterized Bragg scattering. It is appear on the image dark blue color. Volume scattering is dominant by vegetation, it is appear on the image is green color. This indicates that a number of the fallen tree trunks and branches lying on the clear-cut areas may be cause dipole scattering. This is appear on the image is dark green color.

The eigenvector based H/alpha classification leads to an improved understanding of the scattering mechanisms of the target area. The results gave an overview of the utility from SAR polarimetric data to discriminate the forest types, whose analysis procedures were based on the knowledge of the shape from the co-polarized signature and also on the type and intensity of the dominant scattering

Implications

The study will be helpful in case of disaster management and weather hazards, resource identifications and identify the unknown bodies in the forest from space borne satellites, because of presence of plants which grows in a ponds and canals (water bodies), the water bodies appear as a plane land with grass. So during disaster relief the water bodies may be consider as plane land, and may be incur a great loss and hindrance during emergency relief. In the present globalization scenario, identification of micro level bodies over by using microwave technology is playing major role in all aspects of Human developments like identification of natural resources, identification of water bodies and land structure with soil type etc. This technology can be effectively used in differentiating between the space borne bodies such as stars, planets, meteoroids and space craft.

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Biographies

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