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Research Article

Multi-Date Date RISAT-1 FRS 2 Quad Polarization Data Analysis for Various Crop Discrimination

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ABSTRACT

SAR data analysis for classification of crops like transplanted rice and jute has been well established. However, for other heterogeneous crops, the research is still not very conclusive. The multi-polarization information available from SAR data has been found to be useful in assessing various land covers. Indian SAR satellite RISAT-1 Fine Resolution Strip map Mode-2 (FRS-2) provides data with 9 m resolution, 25 km swath and quad-polarization (HH+HV+VV+VH). FRS-2 multi-date data (21st January, 28th February and 25th March 2014) was used to study various crops (Wheat, mustard, gram and pigeon pea) and various land features (natural vegetation, urban, surface water and bare-soil) in the farm area of Indian Agriculture Research Institute (IARI), New Delhi. Ground truth was collected in the study area using smartphones for various crops in rabi season of 2014. Mean and standard deviation of backscattering coefficient of RISAT-1 data acquired over in linear dual polarizations have been analysed for various land features. It has been observed that there was a clear separation of mean σ^0 values of various land cover classes, but there was overlapping of standard deviation of different classes. The multi-date data showed discrimination between various crops.

Key words: RISAT-1, Quad-Polarization, FRS 2, Crop discrimination

Introduction

Synthetic Aperture Radar (SAR) data has shown encouraging results in crop discrimination and classification with reasonably high accuracy (Chakraborty *et al*., 2013). Traditionally, crop classifications were done using multi-date SAR data that uses phenological and cultural type information about crops to discriminate them. Single-date multi-polarization SAR data also has the potential to identify crops based on the variation in their scattering signatures in different polarizations (Haldar *et al*., 2012). The usefulness of multi temporal and multi frequency radar data in agriculture applications in Neitherland was demonstrated by Bouman & Hoekman, 1993. Various authors also found the achieving significant classification accuracies for crops and other land use classes using dual and quad polarimetric data from airborne as well as space borne SARs (Ainsworth *et al*., 2010, Skriver *et al*. 1999, Schotten *et al*., 1995 and Mohan *et al*., 2011).

India's SAR satellite, RISAT-1 (Radar Satellite-1), which was launched in April 2012 is a state of the art Microwave Remote Sensing Satellite carrying a Synthetic Aperture Radar (SAR) payload operating in C-band (5.35 GHz). It is the first spaceborne hybrid PolSAR system (Misra *et al.*, 2013). RISAT-1 supports a variety of resolution and swath requirements. Both

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conventional stripmap and scanSAR modes are supported, with dual polarization mode of operation. Additionally a quad-polarization stripmap mode is provided for availing additional resource classification. De *et al.* (2014) using hybrid polarimetric data from the Indian RISAT-1, found it to be suitable for crop classification as major crops are well distinguished. An overall classification accuracy of 81% and 87% was obtained using May and November 2013 data respectively.

This study was carried out to understand the behaviour of quad-pol data of RISAT-1 FRS 2 mode for discrimination of different crop and land cover classes.

Study area and data sets

For this study, the test site chosen was the agricultural farm of the Indian Agriculture Research Institute (IARI), New Delhi, India. Its location stands at 28.08°N and 77.12°E, the height above mean sea level being 228.61 m total farm area is of 500 hectares. The climate is sub-temperate and semi-arid. The mean maximum temperature during winter (November-March) ranges from 20.1 to 29.1°C and the mean minimum temperature from 5.6 to 12.7°C. During winter, a small amount of rainfall (about 63 mm) is also received. The farm is having area under irrigated and rainfed cropping system. In the study area crops which are grown in rabi season, have been studied, which include wheat, mustard, gram and pigeon pea, analysis was also carried out various land features such as natural vegetation, urban, surface water and bare-soil.

RISAT-1 Fine Resolution Strip map Mode-2 (FRS-2) data with 9 m resolution, 25 km swath and quad-polarization (HH+HV+VV+VH) was used in this study. RISAT-1 data has been acquired on three successive days (21st Jan, 28th Feb and 25th March 2014) over IARI, New Delhi. The details of acquisition mode with incidence angle are given in Table 1.

Methodology

Ground truth collection

Ground truth information were collected from the IARI farm using smart phone through Bhuvan Server using the android application developed by National Remote Sensing Centre (NRSC), Hyderabad (Fig. 1). In the ground truth, all the parameters were uploaded on real time on Bhuvan Server in terms of study crop, field size, crop condition, soil moisture condition, crop cover, date of sowing/harvesting; other competitive crops and photographs etc. were collected using smartphones with parallel to dates of the satellite pass. Ground truth was collected for wheat, mustard, gram, pigeon pea, maize, caster and onion crops. The periods of GT collection was in January, February and March, 2014.

Fig. 1. Ground truth points on Bhuvan portal

Table 1. Details of acquired RISAT-1 FRS-2 quad-polarization data

Quad polarization	Central Inc. Angle	Acquisition Mode	Ground Range/ Azimuth Pixel Spacing (m)	Date of Acquisition (dd/mm/yyyy)
FRS-2 (HH,HV,VH,VV)	34.356°	Ascending/Right Looking	~4m/9m	21/01/2014
FRS-2 (HH,HV,VH,VV)	41.479°	Ascending/Right Looking	~4m/9m	28/02/2014
FRS-2 (HH,HV,VH,VV)	41.478°	Ascending/Right Looking	~4m/9m	25/03/2014

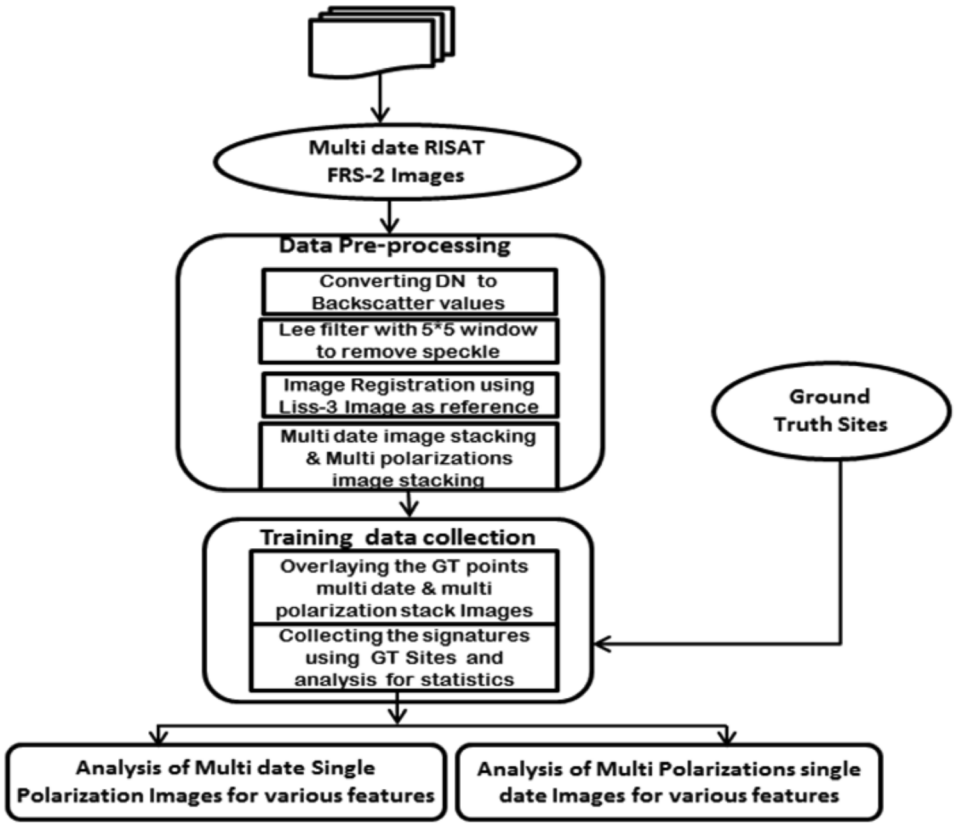

Fig. 2. Flow chart of methodology

SAR data pre-processing

Multi-date RISAT-1 FRS-2 data (21st Jan, 28th Feb and 25th March 2014) were registered with LISS-3 image as referenced image. Calibration constant given in product file is used for converting the digital number in to corresponding backscatter coefficient values. Image was filtered using refined Lee filter with 5*5 window to remove speckle noise. Ground truth was used to generate the mean and standard deviation values for various feature classes. The analysis of multi-date single polarization and single date multi-polarization have been done for various crops (Wheat, mustard, gram and pigeon pea) and various land features (Natural vegetation, urban, surface water and bare-soil). The methodology of data analysis is presented in Figure 2.

Results and Discussion

From the ground truth information, mean and standard deviation of backscattering coefficient of RISAT-1 data of quad-polarization (HH+HV+VV+VH) and multi-temporal data (21st Jan, 28th Feb and 25th March 2014) have been analysed for various crops (Wheat, mustard, gram and pigeon pea) and various land features (Natural vegetation (Forest), urban, surface water and bare land) in the farm and surrounding area of the Indian Agriculture Research Institute (IARI), New Delhi. In this study, we have analysed mean and standard deviation of backscattering coefficient of different land cover classes was done based on the statistics of mean backscatter and deviation from mean. for different classes in four ways.

Mean (σ^odb) values for different classes with quad-polarization data

Fig. 3 shows the mean and standard deviation of the backscattering coefficients (σ^odb) for various classes. A similar trend is exhibited by both linear and dual polarimetric σ^o with the urban class showing the highest mean backscatter and water bodies lowest value. On an average,

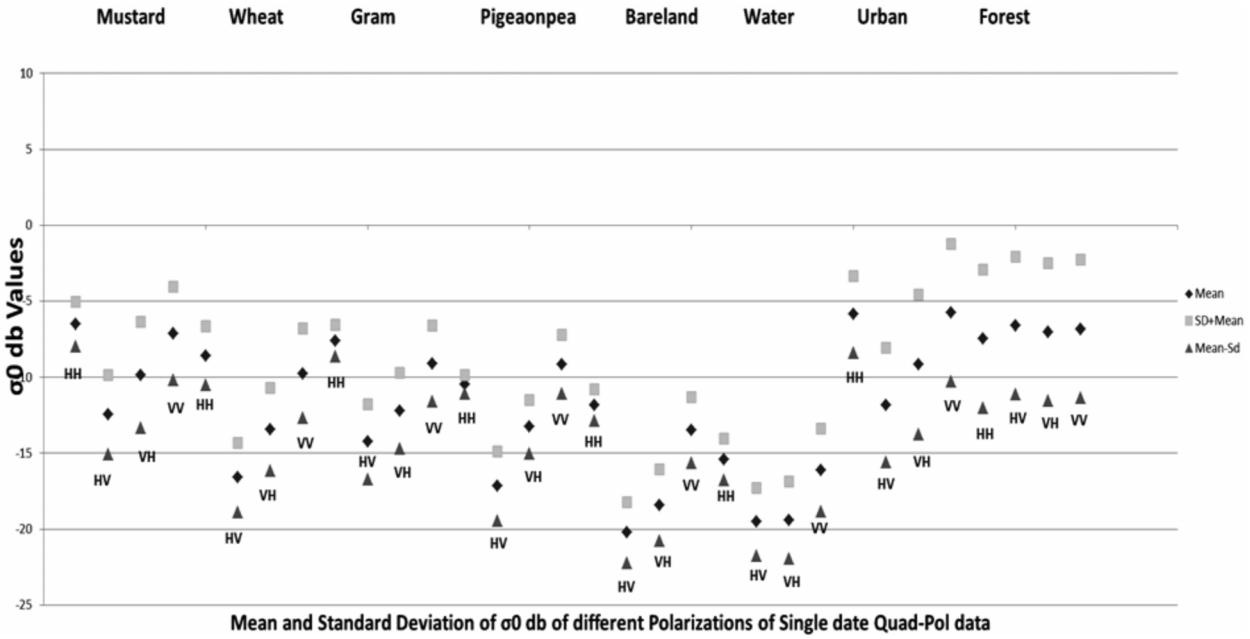

Fig. 3. Mean and standard deviation of the backscattering coefficients (σ0) for quad polarization (HH+HV+VH+VV) for various classes

the HV component exhibits the lowest and HH component shows the highest backscatter values across various classes. HH was close to VV and is higher than VH.

Table 2 gives the mean σ^o db values for each class in different polarization. Although it is found a clear separation of mean values of various classes, but on the basis of backscatter alone, it is difficult to classify the data because standard deviations of various features are high and these overlap the means of other features. For example, wheat and mustard class standard deviations overlap with mean values of each class. There is difference in the incidence angle between the quad-polarization data from RISAT-1. This may be the reason for the difference in mean σ^o db values between the quad polarizations of RISAT-1.

Table 2. σ^o db values for various classes in quad polarization data

Classes	HH	HV	VH	VV
Mustard	-6.52	-12.46	-9.83	-7.12
Wheat	-8.58	-16.60	-13.43	-9.73
Gram	-7.58	-14.23	-12.22	-9.09
Pigeon pea	-10.44	-16.28	-13.17	-11.06
Fallow	-7.22	-17.22	-11.30	-8.39
Bare land	-11.81	-20.23	-18.42	-13.47
Water body	-15.41	-19.52	-19.39	-16.12
Urban	-5.87	-11.83	-9.16	-5.75
Forest	-6.31	-14.25	-11.29	-8.21

Temporal variation of backscatter values of RISAT-1 FRS 2 data

In this multi-date single polarization (HH data) have been shown for different crops. Different crops are sown at different times and have different cropping patterns and growth profiles. Temporal variation of backscatter values will give clear representation for crop discrimination in a heterogeneous area.

Crops are seen separable in terms of backscattering coefficients and crops discrimination is possible using multi-date SAR data. In Figure 4, the temporal variation of backscatter intensity for various crops (Wheat, mustard, gram and pigeon pea) and various land features (Natural vegetation (Forest), urban, surface water and bare land) has been shown.

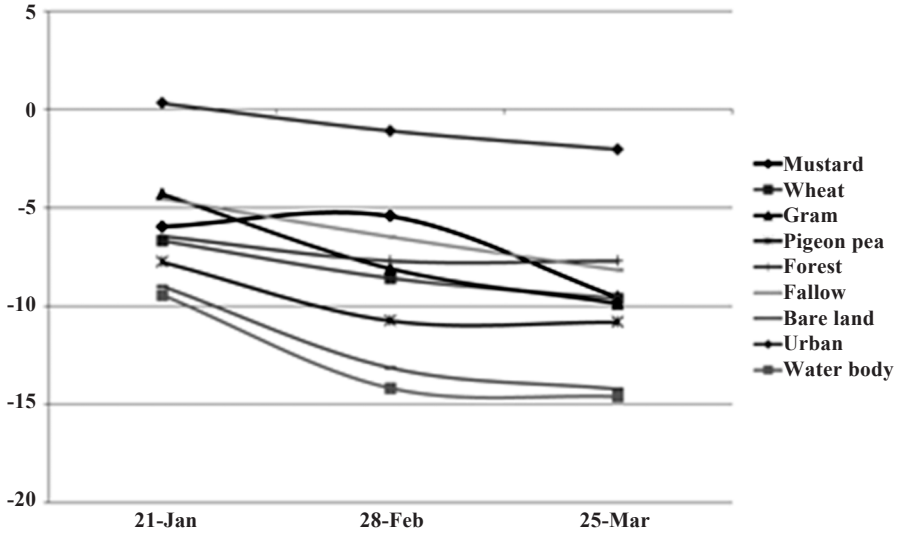

Fig. 4 . Mean (σ^0db) values plot of various classes in HH polarization of three date RISAT-1 FRS-2 data

Mustard was sown in this region during early to mid-October. It is a broad leaf crop and has fast growth rate in the initial phase with peak vegetative phase occurring at mid-January followed by flowering, podding and maturity. Therefore, SAR backscatter values showed increasing trend till February and with further decline due to dropping leaf and pod yellowing.

Gram was sown at a similar time as the mustard but unlike mustard its growth is quite slow resulting the exposure of bare soil moisture and roughness, the backscatter values is high in initially and further decreases due to crop canopy. Pigeon pea is sown in mostly in November and to be harvested in April. If the backscatter decreases with slight increase in March end, it may be due to exposure of soil at matured condition of crop. Urban, water, fallow, forest and bare soil are clearly separable from others as shown in Fig. 4 and Table 3.

Table 3. Mean σo db values for various classes for quad polarization data in different dates

Different classes	Date 1 21-Jan-2014	Date 2 28-Feb-2014	Date3 25-Mar-2014
Mustard	-5.96	-5.43	-9.57
Wheat	-6.68	-8.58	-9.61
Gram	-4.31	-8.10	-9.87
Maize	-6.26	-9.63	-9.77
Pigeon pea	-7.77	-10.75	-10.82
Castor	-5.47	-6.54	-8.48
Forest	-6.45	-7.71	-7.71
Fallow	-4.55	-6.48	-8.17
Bare soil	-8.99	-13.14	-14.22
Urban	0.31	-1.09	-2.03
Water body	-9.44	-14.17	-14.60

Conclusions

In this study, Indian SAR satellite RISAT-1 FRS-2 quad polarization (HH+HV+VV+VH) data and FRS-2 multi-date data (21st January, 28th February and 25th March 2014) were used to study various crops (Wheat, mustard, gram and pigeon pea) and various land features (Natural vegetation, urban, surface water and bare-soil) in the IARI, New Delhi. The purpose of the study was to understand the behaviour of backscattering coefficient (σ0) of RISAT-1 data acquired over the heterogeneous crop area and various land features. Means and standard deviations of backscattering coefficient of RISAT-1 data acquired over in linear dual polarizations have been analysed for various land features. It has been observed that there was a clear separation of mean σ^0 values of various land cover classes and standard deviations from means was overlapping among the classes. With use of multi-date SAR

data, better understanding was found between various classes using the temporal profile of backscatter values.

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