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The usefulness of dual polarization data to discriminate crops from different scattering mechanisms.

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ABSTRACT:
Microwave remote sensing overcomes some of the practical difficulties faced with optical remote sensing, specifically during cloud cover. An important advantage is also that the physical characteristics of crops can be measured to certain extent due to the instrument and signal configuration. Synthetic Aperture Radar (SAR) image data provide unique possibility of acquiring data in all weather conditions. Several studies have used fully polarimetric data for extracting crop information, but it is limited by swath width. This study aimed to study back scatter response from rice & maize crops in hybrid dual polarimetric Radar Imaging Satellite (RISAT)-1 using Fine Resolution Stripmap mode (FRS)-1 data. It also explains the advantage of dual polarized data and the interaction between different crops and land use to different scattering mechanism.

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I. INTRODUCTION:

In India, Rice is the most important cereal food crop and grown in more than 14 major states during the rainy (*Kharif)* season and also in many states during *rabi* season. In India, the *Kharif* season accounts for more than 80 % of the rice cultivation. Maize (*Zea mays*) is a most important crop in the world after wheat and rice. It is grown for food, feed and as an industrial crop, apart from being a major food grain crop supporting food security in several countries. The area under maize crop has increased several fold and the Asia recorded the fastest growth of around 4% in the past decade (Prasanna et al. 2014). The demand is likely to increase further till 2050. However, constraints in the maize productivity are limiting the growth. In India, maize crop is the third most important food grain crop after wheat and rice. It is grown in diverse production environments from a cool, dry area of Chitradurga, Karnataka, to warm, wet plateau of Chindwara, Madhya Pradesh. The annual production of maize in India has increased at a Compound Annual Growth Rate (CAGR) of 5.5% over the last 10 years from 14 million tonnes in 2004-05 to 23 million tonnes in 2013-14. Demand for maize is driven by the poultry and starch industries apart from food additives sector and exports. India exported five million tonnes of maize in 2012-13 which valued at Rs.70 billion (10^9) (Anonymous (2014 a and b)). Water scarcity and government's policy of crop diversification is also promoting the growth of maize crop in non-conventional areas. Availability of region-specifichybrids equal/near equal minimum support price for maize and rice crop is also encouraging farmers to cultivate maize crop which can be grown round the year. But the utility of optical remote sensing in enumeration of rice cropped area is limited due to cloud cover during monsoon. Several studies have been mapped rice area using optical data using MODIS at 500m and 250m meters spatial resolution (Gumma et al., 2011a, 2011b) and temporal AWiFS data (Ramana *et al*. 2014), but it is limited by coarse resolution.

The Synthetic aperture radar (SAR), contrary to optical sensors has all-weather capability. Microwaves respond to the large-scale crop structure like size, shape, orientation of leaves and the dielectric properties of the crop canopy. Crop structure and plant water content vary as a function of crop type, growth stage and crop condition.

II. METHODOLOGY:

2.1 Study area and Data:

West Godavari district is situated on the bank of river Godavari and is known as rice granary of Andhra Pradesh, India. Rice is the major crop in West Godavari district in both *kharif* (rainy) and *rabi* (post rainy) seasons and is grown under irrigated system. The study area located in some part of Achanta Mandal in west Godavari district . Maize study area located in Guntur district of Andhra Pradesh, India (16˚13 ' 17.42 " N, 80˚42 ' 35.57 " E) covering an area of 135 km^2. The climate is warm moist semi-arid/ dry sub humid eco-sub region with medium to deep loamy to clayey mixed red and black soils. In this region, maize is the major crop during *rabi*. It is sown during last week of December or first week of January and harvested in last week of March or first week of April. Apart from maize, pulses such as green gram and black gram were also grown. However, these crops were harvested by the time the data was acquired.

2.2 Data processing:

The processing of RISAT-1 Hybrid Polarimetric single look complex (SLC) data was carried out by using ENVI and PolSARPro image analysis software. The SLC data was downloaded, converted into amplitude format and by applying enhanced lee (Lee *et al*., 1991) speckle filter with 5*5 window speckle noise was removed. Sigma naught image was generated from amplitude DN image by using the following formula (Mayank *et al*., 2014; Manab Chakraborty *et al*., 2013, Iyyappan *et al*., 2014).

$$\sigma_0\,(dB) = 20 * log10(DN_p) - K_{dB} + 10 * log10(\sin(i_p)/\sin(i_{center})) \quad (1)$$

Where,

$\sigma_0\,(dB)$ = The Radar Backscatter coefficient
DN_p = Digital number or the image pixel gray – level count for pixel p
K_{dB} = Calibration constant in dB
i_p = Incidence angle for the pixel position p
i_{center} = incidence angle at the center

III. RESULTS AND DISCUSSION:

3.1 Response of rice crop:

The mean and standard deviation of the backscatter coefficient of various classes is shown in figure 1. The backscatter coefficient of settlement class showed high mean value and that of water showed lowest value. Although, there is a separation of mean values of various classes, it is difficult to classify the data using backscatter alone because of the high standard deviation leading to overlapping of various classes.

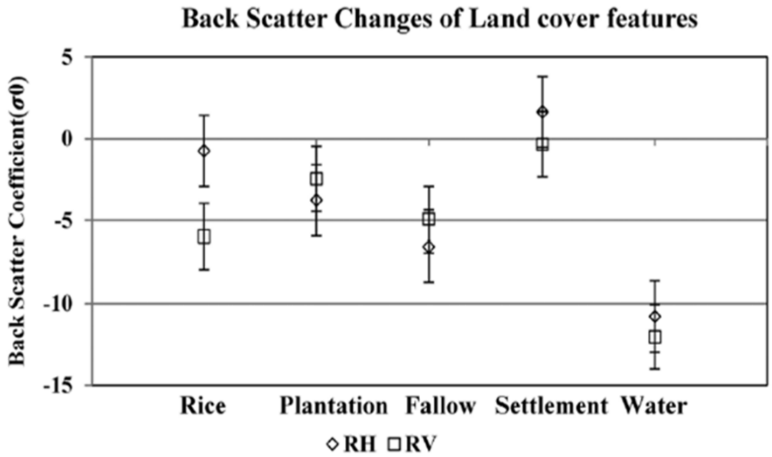

Figure 1: Mean and Standard deviation of Rice and other land use classes

Scattering mechanisms of various type reveal a typical behavior from each crop such as rice along with other lands use. It is observed that rice crop exhibits high magnitude of double bounce scattering followed by settlement and water body because of than other scattering mechanisms. The three decomposition parameters i.e. even, odd and double scattering mechanisms of rice and other classes were shown in the figure 2. The scattering plots of the double vs volume bounce scattering (figure 2a), odd vs volume scattering (figure 2b) for various classes delineated in the study area show that the rice, plantation, settlement, fallow and water were clearly separable.

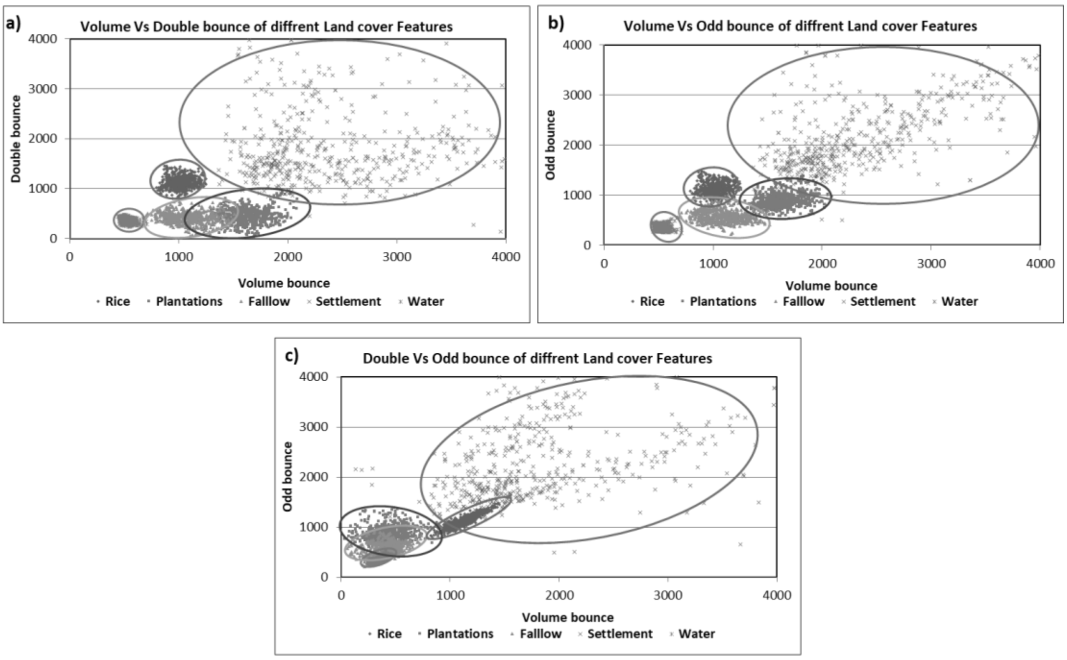

Figure 2: Scatterplot of various scattering mechanisms of rice and other land use classes

The rice crop at reproductive stage is likely to have a scattering mechanism similar to settlement. The settlement class shows high magnitude of double bounce than rice but in periphery of the settlement, it mixes up with rice and other class because of heterogeneity in the scattering mechanisms. The rice crop showed high magnitude of double bounce scattering than odd and volume bounce scattering (Figure 2a and 2b) while in double vs odd scattering plot lot of overlap was observed among the classes (figure 2c). The plantation class showed high volume scattering than odd and double bounce scattering mechanisms because of multiple reflections from tree canopy. The rough fallow showed high magnitude of double or volume scattering than odd bounce scattering. The overall accuracy from RISAT-1 FRS data is 90% while the rice class kappa statistics were found to be 0.92 respectively.

3.2 Response of maize crop:

Mean and standard deviation of backscatter coefficient from RH and RV polarizations for various features is shown in Figure 2. Water exhibits low backscatter than other features and settlements exhibit the highest backscatter. Even though these classes exhibited separation at mean values, high standard deviation lead to overlapping of classes. For example, the backscatter coefficient of RH in peak vegetative stage of maize crop varies between -2 to -10 dB and it overlaps with standard deviation of rough surface from fallow and plantation.

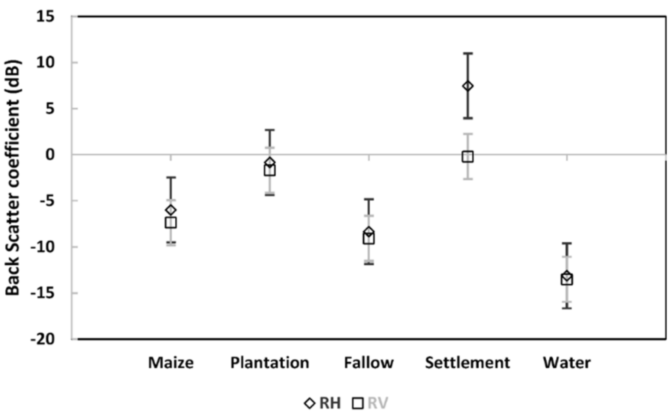

Figure 3: Mean and Standard deviation of Maize and other Land use classes

Peak vegetative stage of maize crop shows high magnitude of volume bounce scattering than odd and double bounce scattering (Figure 4).The two dimensional cluster diagram of volume and double scattering, volume and odd scattering, double and odd scattering for various classes prevalent in the study area show that maize crop, plantation, settlement, fallow and water classes were clearly separable.

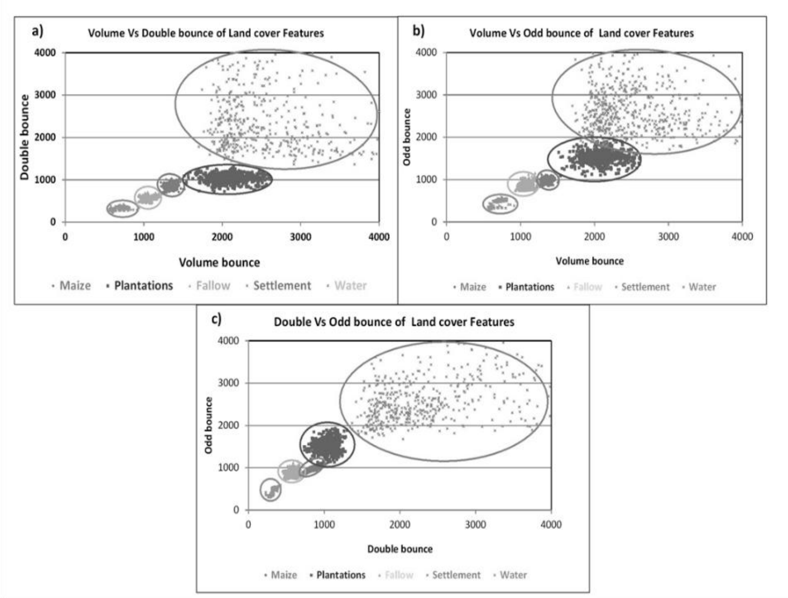

Figure 4: Scatterplot of various scattering mechanisms of Maize and other land use classes

Plantation class has larger canopy than maize which creates multiple reflections from plantation canopy than maize crop. Because of these reasons, high magnitude of volume bounce scattering was observed in plantation class than maize. Overall accuracy of RISAT-1 FRS data is 89.33% respectively. Producer's accuracy of maize crop is 91% from RISAT1 data respectively.

IV. CONCLUSION

Single date hybrid polarimetric data from RISAT-1 is found to be very useful for discrimination of rice and maize crop along with other land use/ land cover. The RH/RV combination shows similar results as obtained from fully polarimetric data and it offers a good compromise between resolution, swath width, incidence angle coverage, cost and information content. Hybrid polarimetric data provides a basis for classifier based on the structural characteristics of the target and it was suited for maize crop discrimination while the standing water during rice crop growth makes it easier for discrimination.

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