



Sentinel 1A SAR Backscattering Signature of Maize and Cotton Crops

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Crop discrimination is a key issue for agricultural monitoring using remote sensing techniques. Synthetic Aperture Radar (SAR) data are advantageous for crop monitoring and classification because of their all-weather imaging capabilities. The multi-temporal Sentinel 1A SAR data was acquired from 08th August, 2015 to 23rd January, 2016 at 12 days interval covering the extent of Perambalur district of Tamil Nadu. Both the Vertical - Vertical (VV) and Vertical-Horizontal (VH) polarized data are compared. The ground truth data collection was performed for cotton and maize during the vegetative, flowering and harvesting stages. The temporal backscattering coefficient (σ^0) for cotton and maize are extracted using the training datasets. The mean backscattering values for cotton during the entire cropping period ranges from -10.58 dB to -6.28 dB and -20.59 dB to -14.53 dB for VV and VH polarized data respectively, and for maize it ranges from -11.08 dB to -7.07 dB and -19.85 dB to -14.14 dB for VV and VH polarized data respectively.

Key words: Sentinel 1A, SAR Backscattering signature, Maize, Cotton

Agricultural crops are the important food source for most of the terrestrial species. As a result, the monitoring of crops and their growth stages and discrimination between the crops are considered most important. Monitoring the crop phenology and observing their conditions within the growing season allows the farmers to modify the cultivation practice as needed. Crop discrimination is a critical first step which allows to discriminate between crop types, mapping the cropped area and estimating the yield at early stage. For these purposes, the use of remote sensing is essential. Optical remote sensing for crop monitoring has increased over the past several years and become one of the major civilian operational applications. However, several images acquired at specific times during the crop growth cycle are required to reach a suitable accuracy. This temporal constraint limits the use of optical data for operational applications because cloud cover may prevent or delay image acquisitions in many places. Space borne Synthetic Aperture Radar (SAR) imagery is able to observe the Earth's surface independently of such conditions as cloud cover and guarantees a temporal frequency of images throughout the growing period (Boerner *et al.*, 1987).

In the case of SAR polarimetry, the sensitivity of microwave polarization to crop structure (size, shape, and orientation of leaves, stalks, and fruits), dielectric properties (related to the water content), and the physical properties of the underlying soil (roughness and moisture) varies as a function of crop type, growth stage and crop condition (Haldar *et al.*, 2012 and Iyyappan *et al.*, 2014). As a fact, different crops types, or the same type at different growth stages,

produce different polarimetric signatures, which can be identified in the acquired images. The objective of this paper is to exploit the potential of polarimetric Sentinel 1A SAR data for monitoring and extraction of backscattering signature at different phenological stages of Maize and Cotton crop in Perambalur district of Tamil Nadu.

Material and Methods

Sentinel1-A, carrying a C-band radar system with VV (Vertical-Vertical) and VH (Vertical-Horizontal) polarization obtained by interferometric wide (IW) swath mode (1) of High Resolution (HR) and processed at Level-1 ground range (GRD) is used for this study. In order to have a full coverage during the crop growing period of Maize and Cotton in Perambalur district of Tamil Nadu, the Sentinel 1A data were downloaded from 8th August 2015 to 23rd January 2016 at 12 days interval from the Sentinel Scientific Data Hub – Copernicus website (<https://scihub.copernicus.eu/dhus/>). The satellite pass is not available between 1st September 2015 and 19th October 2015.

Pre-processing of the satellite images were performed to suppress the unwanted distortion or to enhance the image features important for further processing. The pre-processing operations like Orbital correction, Subsetting, Border Noise Removal (Carlo, 2015), Radiometric calibration (Rosich and Meadows, 2004; Laur *et al.*, 2004 and Lavelle and Wright, 2009), Geometric correction (Range Doppler Terrain Method), Co-registration, Layer stacking, Multi-temporal speckle filtering (Quegan *et al.*, 2000) and Linear to dB conversion was done using Sentinel 1 toolbox.

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The ground survey was conducted during the month of October, November and December 2015 in the cotton and maize growing areas for extraction of backscattering signatures. The survey was planned in such a manner to collect information at different stages of the crop viz., vegetative, tasseling / boll formation and harvesting. Totally sixty-nine points were surveyed for maize (39 points) and cotton (30 points) and they were geocoded using the GPS Latitude and Longitude

values using Sentinel 1 toolbox. Further, the temporal backscattering signature values were derived using the geocoded points for V-V and V-H polarization separately for further analysis.

Results and Discussion

The radar backscattering coefficient (σ_0) is a measure of crop biomass, plant height, water content, underlying soil, crop phenology etc. The SAR data

Table 1. Temporal backscattering signature (σ_0 values) for Cotton

Date of Satellite pass	VV Polarization			VH Polarization		
	Minimum (dB)	Maximum (dB)	Mean (dB)	Minimum (dB)	Maximum (dB)	Mean (dB)
08-Aug-15 (D1)	-12.62	-7.53	-10.58	-20.05	-16.33	-20.59
20-Aug-15 (D2)	-12.79	-6.11	-9.78	-19.88	-16.15	-19.87
01-Sep-15 (D3)	-12.90	-7.20	-10.34	-19.38	-16.52	-20.35
19-Oct-15 (D4)	-10.25	-4.34	-7.43	-16.32	-14.11	-16.13
31-Oct-15 (D5)	-9.56	-2.67	-6.28	-14.87	-13.05	-14.96
12-Nov-15 (D6)	-9.68	-4.22	-7.08	-14.47	-13.33	-15.23
24-Nov-15 (D7)	-9.52	-5.01	-7.05	-14.99	-13.59	-14.89
06-Dec-15 (D8)	-10.22	-4.32	-7.68	-14.67	-13.01	-14.53
18-Dec-15 (D9)	-10.26	-4.99	-7.57	-15.17	-13.59	-15.24
30-Dec-15 (D10)	-11.57	-5.26	-8.34	-16.59	-13.83	-16.35
11-Jan-16 (D11)	-11.91	-6.61	-8.59	-16.52	-14.39	-16.27
23-Jan-16 (D12)	-12.02	-3.74	-9.11	-16.80	-14.44	-16.51

collected during the cropping period were processed and analyzed using the training pixels to derive the temporal backscattering coefficient (σ_0) for Cotton

and Maize. The minimum, maximum and mean temporal backscattering signature for Vertical-Vertical (VV) and Vertical-Horizontal (VH) polarized SAR data

Table 2. Temporal backscattering signature (σ_0 values) for Maize

Date of Satellite pass	VV Polarization			VH Polarization		
	Minimum (dB)	Maximum (dB)	Mean (dB)	Minimum (dB)	Maximum (dB)	Mean (dB)
08-Aug-15 (D1)	-13.77	-1.52	-11.08	-23.19	-15.51	-19.85
20-Aug-15 (D2)	-12.86	-1.20	-10.00	-22.87	-16.14	-19.37
01-Sep-15 (D3)	-13.25	-1.35	-10.28	-23.04	-16.12	-19.39
19-Oct-15 (D4)	-12.09	1.20	-8.48	-18.83	-12.15	-16.07
31-Oct-15 (D5)	-9.19	1.86	-7.07	-16.53	-11.54	-14.40
12-Nov-15 (D6)	-10.56	1.33	-7.75	-17.26	-11.93	-14.89
24-Nov-15 (D7)	-10.61	1.11	-7.73	-16.72	-11.80	-14.47
06-Dec-15 (D8)	-10.48	-0.89	-8.33	-16.44	-11.01	-14.14
18-Dec-15 (D9)	-11.28	-0.32	-8.47	-17.38	-11.99	-14.92
30-Dec-15 (D10)	-12.32	-1.02	-9.59	-18.39	-13.66	-16.17
11-Jan-16 (D11)	-13.56	-1.41	-10.03	-18.54	-13.35	-16.37
23-Jan-16 (D12)	-14.30	-1.63	-10.46	-19.87	-13.38	-16.76

for cotton and maize are given in Tables 1 and 2. The mean backscattering values for cotton crop during the entire cropping period ranges from -10.58 dB to -6.28 dB and from -20.59 dB to -14.53 dB for VV and

The mean backscatter value for cotton crop during the harvest (σ^0D10) to post harvest stage (σ^0D12) has decreased to the maximum of 1.54 dB in VV and 1.27 in VH when compared to the developed

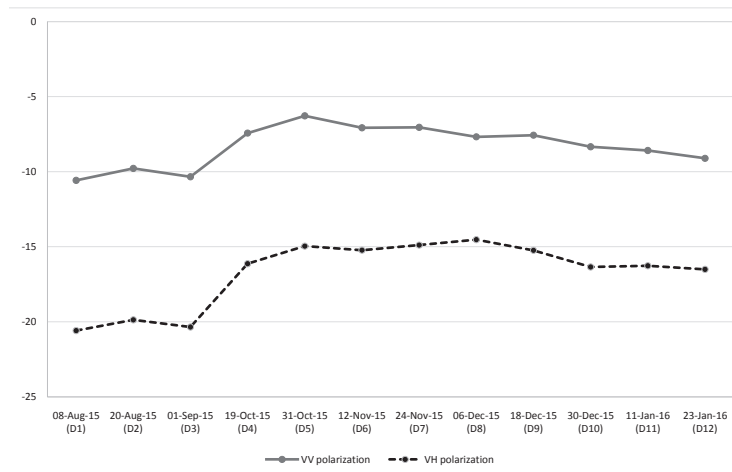


Fig 1. Mean Temporal backscattering signature of Cotton crop

VH polarization respectively. For maize crop it ranges from -11.08 dB to -7.07 dB and from -19.85 dB to -14.14 dB for VV and VH polarized data respectively. When comparing the mean σ^0 of VH with VV polarization of cotton crop, it is found that VV backscattering is lesser by 9.66 dB to 13.76 dB at different stages of crop growth. Similarly, for maize crop, backscattering is lesser by 5.82 dB to 9.37 dB. This shows that VV polarization is more sensitive in acquiring the surface variation than VH and this in line with work reported by Aubert *et al.* (2011).

crop stage of σ^0D9 . Similar trend was found in the maize signature and values were decreased to the maximum of 1.99 dB in VV and 1.84 dB in VH polarization. The decrease in backscatter value may probably due to the maturity of crop, which lowers the water content of vegetation (Lillesand and Kiefer, 1994) or related to the vegetation biomass (Skriver *et al.*, 1999) and or related to the reduced volumetric scattering due to maturity (drying and fall of lower leaves) (Panigrahy and Mishra, 2003). In both VV and VH, the mean backscatter scatter value for cotton

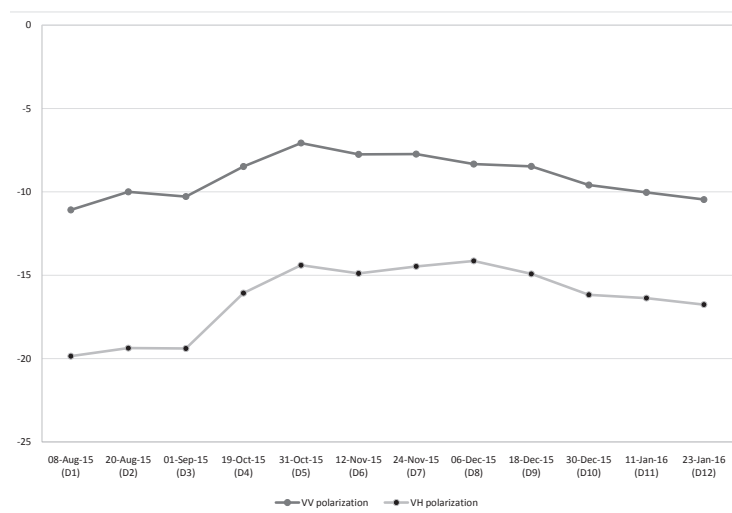


Fig 2. Mean Temporal backscattering signature of Maize crop

In both cotton and maize signature it is found that the mean backscatter value during the land preparation (σ^0D1) to initial crop growth period (σ^0D3) shows lesser scattering in both VV and VH when compared to the further crop development stages (σ^0D4 to σ^0D9). This might be the due to soil moisture variation (Xavier Blaes and Pierre Defourny, 2003) or sowing which made the soil surface smoother (Karjalainen *et al.*, 2004).

crop has increased by around 4.0 dB during the vegetative, flowering and boll formation stages (σ^0D4 to σ^0D9) when compared to the initial establishment period (σ^0D3) (Fig 1). Similar trend was found in maize signature and it shows an increase in mean backscatter scatter value ranges from 3 to 5 dB during the vegetative, flowering and cob formation stages (σ^0D4 to σ^0D9) (Fig 2). The increase in mean backscattering may be caused due to the increase in

vegetation biomass as reported by Xavier Blaes and Pierre Defourny (2003). While comparing the mean backscattering values of cotton and maize at the peak crop growth stage (σ^0D4 to σ^0D9) shows an increase in value of 1.0 dB to 2 dB was observed and it clearly indicates that the crop geometry, volumetric backscattering from crop canopy and biomass leads to this increase (Fig 1 and Fig 2). Several research works are in line with these results (Haldar *et al.*, 2014, Shang *et al.*, 2009 and Xavier Blaes and Pierre Defourny, 2003)

While considering the entire crop period of cotton, the minimum backscattering value of -12.90 dB at σ^0D3 and -20.05 dB at σ^0D1 is recorded during the land preparation stage for VV and VH polarization respectively. Similarly, the maximum backscattering value of -2.67 at σ^0D5 and -13.01 dB at σ^0D8 is recorded during the vegetative to boll formation stage for VV and VH polarization respectively. In case of maize, the minimum backscattering value of -14.30 dB at σ^0D12 and -22.87 dB at σ^0D2 is recorded during the land preparation stage for VV and VH polarization respectively and the maximum backscattering value of 1.86 at σ^0D5 and -11.01 dB at σ^0D8 is recorded during the vegetative to cob formation stage for VV and VH polarization respectively. From the above results it clear that the maize crop has recorded the highest backscattering value during the peak growth stage and this might be due to higher biomass content in maize when compared to cotton crop. This is line with the work done by Soria-Ruiz *et al.* (2001) and Macelloni *et al.* (2001).

Conclusion

It is evident from the present study, that the multi-temporal Sentinel 1-A SAR sensor can be well used for the discrimination of cotton and maize crops because of its high temporal resolution which captures the complete phenology of the crops during the cropping period.

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