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Time series Sentinel-1A profile analysis for heterogeneous Kharif crops discrimination in North India

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Abstract

The current research analyze the potential of dual-polarized C-band Sentinel-1A Datasets for temporal profile extraction to discriminate different kharif crops. The study was carried out over the parts of Agra District during Kharif season from June to September 2018, where the region consists of multiple crops like Cotton, Bajra, Fodder Jowar, Maize, Sesbania, Arhar and Paddy. The temporal backscatter behavior of crops were extracted from eight date Sentinel -1 amplitude datasets. The availability of multi-date SAR data helps in identifying various crops based on their difference in phenology. Similar growing crops like Jowar, Maize, Sorghum and Bajra were separated using the difference in crop calendar dates. In VV profile, the backscatter of Paddy ranges from -18 dB (during transplantation) and as the crop grows, it reaches maximum up to -7 dB. Based on the backscattering behavior, timely transplanted and late transplanted paddy were identified. Sesbania and Arhar, already reached peak vegetative growth in the first date, shows high VV backscatter range of -9 to -7 dB but these crops were separated by their rate of growth, as Arhar shows less growth rate than Sesbania. Based on VH and VV backscatter changes, Cotton was further separated as Desi Cotton and Bt Cotton showing different profiles. Due to frequent cutting of Jowar crop for fodder purposes, unique signature pattern of multiple dip and rise in VV and VH profile was observed. For coarse millet Bajra, changes in backscatter was in the order of -13 to -8 dB in VV and -21 to -12 dB in VH polarization. The study reveals that heavy rainfall during image acquisitions impacts the backscattering values, as it has direct relationship with crop dielectric constant, soil moisture, soil roughness and other canopy parameters. Based on the temporal backscatter values, Hierarchical Decision rule model was framed and crop classification was attempted. Paddy was classified around 85 - 90% accuracy and all other crops achieved around 70% classification accuracy.

1. Introduction

Major crops like rice, millets, cotton, groundnut etc. are grown during kharif season in India, so continuous crop monitoring and mapping is not possible with optical data due to cloud cover. Due to all weather capability of radar waves, microwave remote sensing has the ability to provide cloud free data. Apart from this, the unique sensitivity of radar waves to crop canopy structure, size, orientation, dielectric constant and roughness enables to get complementary information than optical data which takes account of only spectral reflectance of crop [1].The dielectric content and structure of vegetation varies as crop undergoes various growth stages starting from earlier vegetative to senescence, capturing these temporal changes is the most important aspect for identifying different crops[2]

It is evident from the previous studies that backscatter response increases in accordance with crop growth cycle due to volume scattering. Analysis of Multi-temporal SAR data found to be more promising for discriminating different crop types by capturing dynamic random scattering occurring in crops throughout the entire growth cycle [3]

Previous research shows that the availability of multi-frequency, multi-temporal, multi-polarization leads to efficient discrimination of crops and further increases the classification accuracies[2]. Temporal amplitude SAR datasets finds promising for monitoring of rice crop [3,4]. The backscatter extracted from multi-temporal amplitude data was found to be promising in discriminate jute crop and able to achieve the classification accuracy of 91 percent [5]. The temporal profiles derived from time-series amplitude backscatter was used alone to discriminate paddy and cotton [6].

2. Study Site and Data Collection

The study was done over the parts of Agra district located in Uttar Pradesh covering an area of about 4027 km^2. The area is bounded by 27^{0}10’59’’ N latitude 78^{0}01’00’’E longitude, with an average elevation of 166 m above m.s.l. The average annual rainfall (2009-2017) is 655.5mm. The overall trend shows that there is a decrease in rainfall over years from 2010 to 2017 and current year 2018 receives high rainfall of about 728.9mm (World Weather Online).

The study area is a mixed crop region with Sesbania, paddy, Jowar, sorghum, maize, Bajra, Cotton, Arhar and some vegetable crops like chili, bottle guard, etc. Paddy is transplanted in the mid of July to first of August. Jowar and Maize are sown during end of May and almost reaches harvesting stage in August. Sowing of Bajra crop commence from the end of June and continues till end of July. Among cotton, Desi cotton was sown early during May and Bt-cotton was sown in the month of June.

Eight date Sentinel-1A GRD datasets of 12 days temporal resolution was downloaded from freely available Copernicus Data hub provided by European Space Agency.

Table 1. Sentinel-1A data specifications used for the study

Sensor	Polarization	Frequency	Incidence Angle	Acquisition Dates (2008)	Acquisition Mode
Sentinel-1A	VV+VH	C-band (5.405 GHz)	30.74^0 - 46.25^0	27th June, 9th July, 21st July, 2nd Aug, 14th Aug, 26th Aug, 7th Sep and 19th Sep	Interferometric Wide Mode (IW) with 250 km swath

Ground truth data were collected in synchronous to satellite pass. The coordinates of the crop field was marked with GPS (Global Positioning System) receiver. Plant parameters like crop sowing/transplanted date, crop stage, crop vigor, crop height, crop percentage cover, leaf Area Index of different crops and soil parameters like soil moisture and roughness were collected. The same crop fields were surveyed multiple times to observe the changes in crop phenology and minimum 20 sampling points per crop was collected.

3. Methodology

3.1 Data pre-processing

Sentinel-1A temporal datasets were pre-processed using SNAP 6.0 software. The orbit file correction was carried out to update the metadata with precise orbit vectors. The study area consists of mostly agricultural areas with varied crops leading to random scattering process. For such heterogeneous areas, non-adaptive filter like Boxcar and median are not suitable as it averages the coherency or covariance matrices of neighboring pixels leading to blurring of sharp edges and over filtering of point targets, which converts it to spread targets[7].

For this particular scene, adaptive filter Lee Sigma filter of window size 5X5 was found to be effective as it is based on local statistics (standard deviation) calculated within the each filtering window of the image. It removes the speckles without compromising the edge sharpness, scattering mechanisms and preserves finer image details [8]. For comparing values of multi-temporal datasets and for various parameter characterization, radiometric calibration of SAR data is done and converted to dB scale [9]. Finally the temporal images are registered with first date master image and made as eight date stack.

3.2 Characteristic Profile Extraction and Classification

The ground truth points (20 points per crop) were overlaid over the stacked images and ROI were created for different crops. Based on the ROI statistics, characteristic temporal profiles of different crops were extracted and backscattering changes were plotted for temporal time period across 8 dates. DT classification provides better crop discrimination and classification accuracy when SAR Data were used in the study [10]. Decision rule was developed based on temporal backscattering response of different crops in both VV and VH polarizations.

4. Results and Discussion

4.1 Amplitude Data Profile Analysis

Amplitude data is used for discrimination of various crop in the mixed crop scenario region. Paddy shows significant characteristic temporal profile which makes it easy to discriminate from other crops. Both VV and VH shows same backscattering pattern, only intensity differs. The dip in the graph indicates the transplantation stage of rice where the backscatter ranges from -18 to -15 dB as seen in **Figure 1**. Based on this, timely transplanted and late transplanted rice was identified.

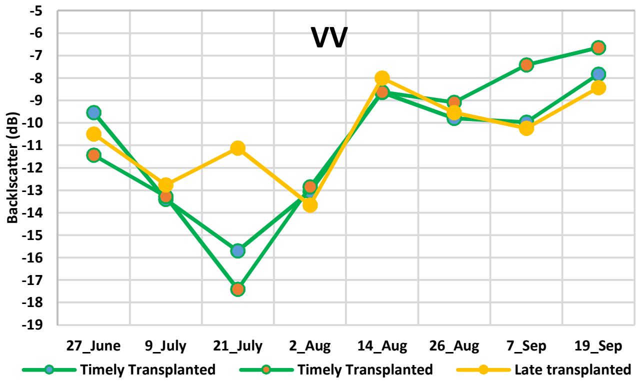
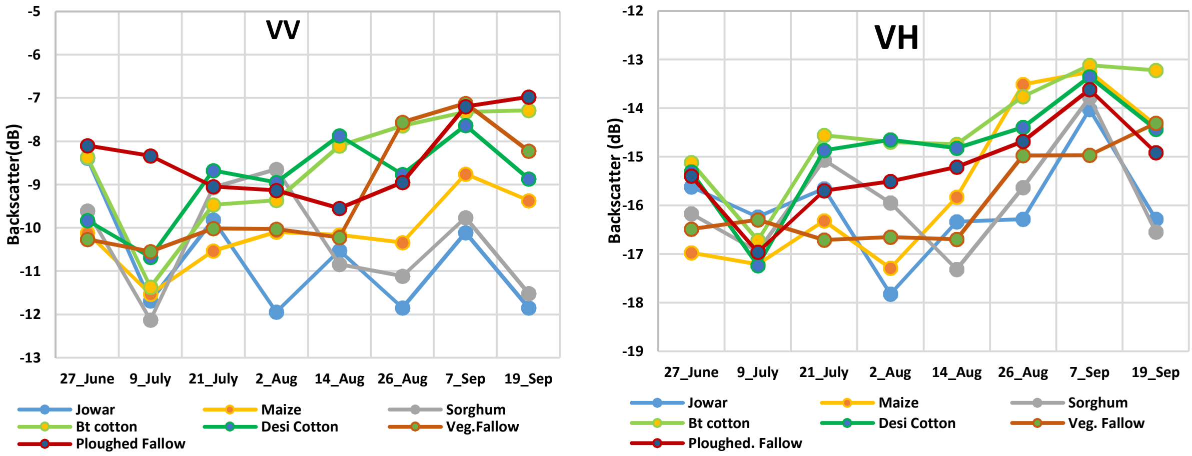


Figure 1. Temporal backscatter response of paddy in VV

The backscatter from paddy canopy increased up to -7 dB (shown in **Figure 1**) when plant volume increases and reaches peak vegetative stage. In VH, backscattering for paddy was in the range of -21 dB to -14 dB. Similarly for other crops like cotton, desi cotton ranges from -10 to -8 dB (**Figure 2**), shows high backscattering in the initial dates as the crop was early sown reached peak vegetative stage in early July and also due to high soil moisture. Bt-cotton shows backscattering in the range of -12 to -7 dB. The vegetated and ploughed fallow fields shows distinct profiles in VV when compared with VH polarization. Ploughed fallow because of high surface roughness shows high backscatter of -8 dB in the first date **(Figure 2 (a)),** slightly started to decrease in the upcoming dates, as the continuous rainfall reduces the soil roughness. Both vegetated and ploughed fields shows constant backscattering from end of July to end of Aug, and then backscattering response increases. This is because of again ploughing of smooth field and in vegetated field, this is due to the growth of tall grass and weeds.

polarization. Bajra crop sown in the end of June, shows dip in first July due to waterlogging in fields in both polarization. As crop grows, backscattering increases from -13 to -8 dB in VV and -19 to -13 dB in VH polarization.

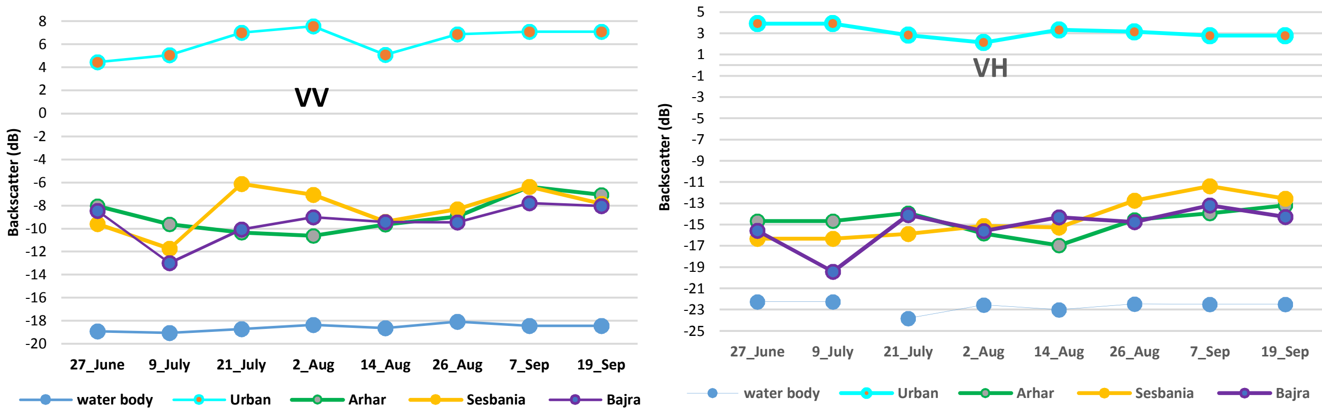


(a) (b)

Figure 2. Temporal response of cotton, Jowar, maize, sorghum and fallow fields in VV (a), VH (b) polarizations

The backscattering of maize was in the range of -12 to -9 dB. Sorghum shows less backscattering when compared with other crops like maize and cotton in both VV and VH polarizations **(Figure 2 (a), (b))**. The dip in the profile of various crops is due to rainfall and this was verified using ground truth visits. Jowar, which is used as fodder crop in

Urban due to double bounce scattering shows very high backscattering of more than 1 in both the polarization and water body due to occurring of surface scattering shows very low backscattering of less than -18 dB in VV and -20 dB in VH.



(a) (b)

Figure 3. Temporal response of Sesbania, Arhar, Bajra, water body and urban in VV (a) and VH (b) polarization

the region shows alternate rise and dip in backscattering due to frequent cutting of crop which is noticed in both the polarizations **(Figure 2(a), (b))**.

Arhar shows slow growth rate when compared with other crops in the range of -10 to -7 dB in VV and -18 to -14 dB in VH polarizations as seen in the **Figure 3 (a), (b).** Sesbania being high biomass crop, almost 6 to 8 feet tall reaches high backscattering up to -6 dB. The dip in the 9th July around -12 dB in VV polarization as shown in **Figure 3(a)** was observed due to standing water in the Sesbania fields and this was not captured in the VH

4.2 DT classification

The cyan patches indicates timely transplanted rice and blue patches indicate late transplanted rice as shown in **Figure 4 (b).** The bright green patches indicates Sesbania and dark green are Arhar **(Figure 4 (c))** and along with other crops like maize, Jowar and cotton. The magenta color shows the Bajra fields and pink shows cotton fields as seen in **Figure 4 (d)**.

Before framing decision rules, band separability analysis using Transformed Divergence Method was done to select the bands providing maximum separability among various crops. With the four date selected bands (July, Aug, and Sep) DT rule was framed to classify various kharif crops.

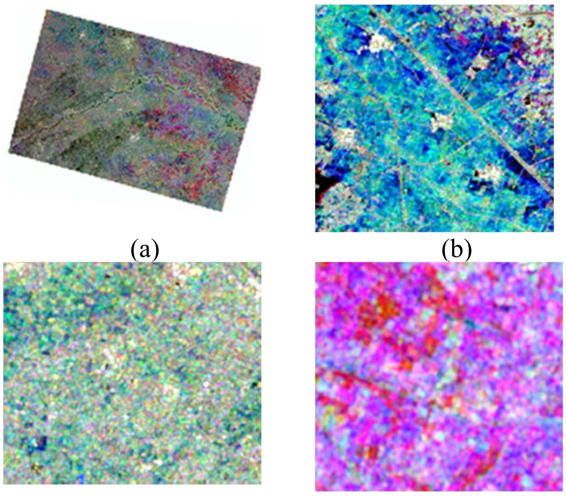


Figure 4. FFC of three date Sentinel-1A VV Dataset (a), Zoom in view of paddy (b), other mixed crops (c) and Bajra fields and cotton (d) in FCC image.

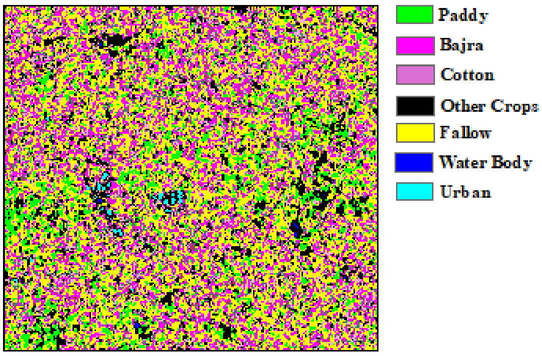


Figure 5. Sentinel-1A classified image using DT rule

Based on the dB temporal response, paddy crop (green color in **Figure 5**) was distinguished from other crops and able to achieve 85 - 90% accuracy. Other crops like Bajra, Jowar, Sesbania, Arhar and cotton were classified around 70% accuracy.

5 Conclusion

The study has demonstrated the potential of Sentinel-1A in crop discrimination studies. The use of multi-temporal single polarization (VV) provides better crop discrimination and classification results than using both VV and VH polarization. The results are encouraging for individual crop classes like paddy and Bajra which shows high classification accuracy. The mixing of similar growing crops like sorghum, Jowar and maize was noticed in the present study. To further overcome this, a parallel study is taken up to discriminate closely structured crops like fodder Jowar, Bajra, maize and sorghum using potential multi-date full polarimetric data Radarsat-2 data.

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7. References

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