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MULTI-TEMPORAL SAR DATA FOR DISCRIMINATION AND AREA ESTIMATION OF COTTON CROP-A STUDY FROM SIRSA DISTRICT, HARYANA, INDIA

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ABSTRACT

The present study was carried out for identification of cotton crop using multi-date Sentinel-1A C-band Synthetic Aperture Radar (SAR) data in Sirsa district which falls in north-western part of Haryana state. Multi-date SAR images from May 2019 to September 2019 covering all main phenological stages of cotton crop were downloaded. SAR backscatter values for cotton and other associated kharif crops were noted on multi-date SAR data. The hierarchical decision rules were used for discrimination of cotton crop with other land use/ land cover classes. The study demonstrates the potential of C-band VV polarized SAR data for the classification and acreage estimation of cotton crop. The total area of cotton crop obtained by the analysis of the multi-date SAR data using hierarchical rule-based classification was 152700ha. The cotton area was compared with the cotton area statistics obtained from Department of Agriculture & Farmers Welfare, Haryana and the relative deviation (RD) of -8.78% was observed between the field and satellite analyzed data. The overall accuracy was found 87.27%. The finding of the study reveals that multi-temporal Sentinel-1A VV polarized C-band SAR data can be used to develop an operational cotton crop identification and discrimination framework where availability of optical band data is difficult to obtain due to cloud cover.

Keywords: Cotton, Sentinel-1A, Backscattering, SAR, Hierarchical Decision Rules, Sirsa, Haryana.

INTRODUCTION

Haryana is an agriculture dominant state. In the state about 65.21% population is engaged in agriculture related practices. Monitoring of crops using satellite data is important to know the production in the state for future planning. Optical satellite data are available during clear environmental conditions but during rain, cloud and night microwave satellite data are highly useful.

In kharif season, cotton is one of the important fiber and cash crop grown in north-western and south-western parts of Haryana. The crop is mainly sown in medium textured well-drained soils. The cotton crop is a long duration crop matures in 150-180 days. Sirsa, Fatehabad, Hisar, Bhiwani, Charkhi Dadri and Jind are the main cotton growing districts in the Haryana state. In the cotton growing season (June-September) the cloud cover restrict the operational use of the optical sensors. Synthetic Aperture Radar (SAR) being an active system operates in the microwave region of the electromagnetic spectrum having the wavelength ranging from 1 mm to 1 m. Due to longer wavelength, the microwaves can easily penetrate through the clouds and can provide cloud free all-weather data for monitoring the crops in the kharif season. Haldar *et al*., 2011 conducted a study on cotton crop acreage estimation and biophysical parameters using multi-polarization and multi-frequency SAR data.

The high temporal resolution of Sentinel-1A allows assessing the crop growth and crop discrimination. The characteristic of C-band SAR enables applications in agriculture during kharif season. Sensitivity of SAR data to crop geometry, crop structure and moisture content can be suitably exploited for the crop discrimination. Dave *et al.*, 2019 used multi-date RISAT-1 SAR data for identification of cotton crop in Gujarat. The results of various studies indicate that as the crop grows, backscattering increases due to volume scattering from the crop. So, it is observed that multi-date SAR data is very useful for discrimination of various crops.

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STUDY AREA

Sirsa district falls in the north-western part of Haryana State and lies between 29º14′ N to 29°59′ N latitudes and 74°27′ E to 75°18′ E longitudes, covering an area of 4277 sq. km. (Fig.1). Sirsa district is surrounded by Faridkot and Bhatinda districts of Punjab state in the north and north-east, Ganganagar and Hanumangarh districts of Rajasthan state in the west and south and Fatehabad district of Haryana in the east. The average annual rainfall in the district is 222.72 mm. About 83% of average annual rainfall is received during the months of June to September.

In the district, mainly three soil orders i.e. Entisols, Inceptisols and Aridisols are found. The major part of the district is occupied by Typic Comborthids and Typic Torripsamments soils but Vertic Heplustepts and Typic Ustifluvents are also found in low lying areas. In major parts of the district soil texture varies from loamy sand to sandy loam but loam to clay loam texture is also found in low lying areas.

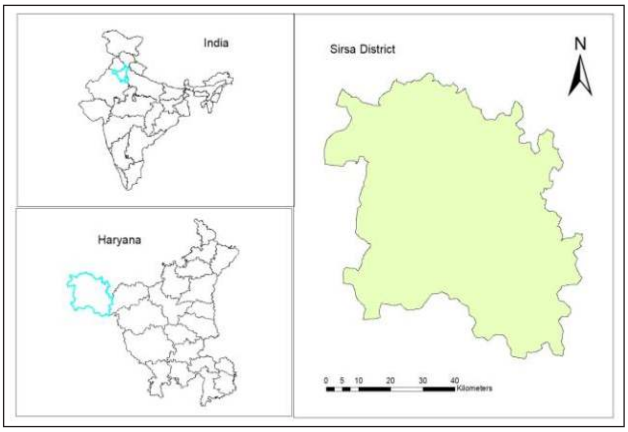

Fig.1: Location Map of the Study Area

MATERIALS AND METHODS

Data Used

Sentinel-1A multi-date SAR data was used for estimation of cotton crop in the study area. The satellite Sentinel-1A having C-band Synthetic Aperture Radar (SAR) provides all weather day and night data at temporal resolution of 12 days. It has four different operational modes-Interferometric Wide Swath (IW), Wave (WV), Strip map (SM) and Extra Wide Swath (EW). In the present study high resolution Level-1 IW, Ground Range Detected (GRD), ascending order VV polarized multi-date images have been used.

In the present study, ground truth (GT) points were downloaded from the Bhuvan FASAL portal developed by National Remote Sensing Centre (NRSC), ISRO. The ground truth data includes location in the form of latitude and longitude, field photographs and field parameters. This data was used to classify the satellite data for acreage estimation of cotton crop in the study area. Fig. 2 shows ground truth points overlaid on the satellite imagery of the study area.

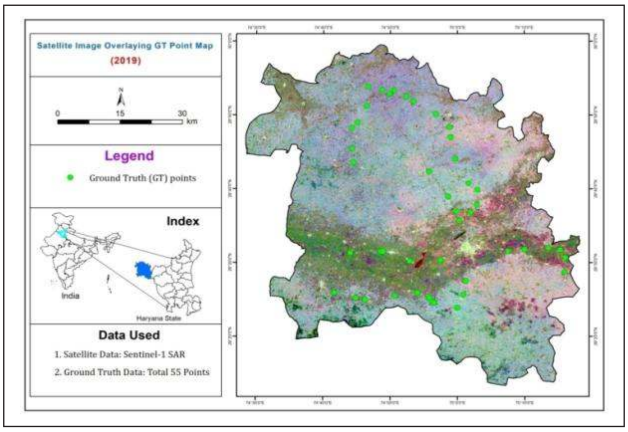

Fig.2: Ground Truth Points overlaid on satellite data.

Methodology

Sentinel-1A SAR multi-date data from May 2019 to September 2019 were downloaded and preprocessed by following the standard procedure of apply orbit file, calibration, multi-looking, speckle filtering and terrain correction. The multi-date preprocessed images were co-registered and a data stack was formed covering all the acquisitions. Using GT points, temporal backscatter values were noted for the cotton, other associated kharif crops and various land cover features. Each crop has different growing pattern, date of sowing, differences in moisture content, crop biomass, plant height and plant density per meter square. Due to variation in these characteristics, a significant difference in backscatter values for different crops in multi-date SAR data was observed during their growing period.

A knowledge base was developed using the understanding of the date of sowing, peak vegetative stage, harvesting stage and cropping pattern of cotton crop and hierarchical decision rules were formed. The analysis and discrimination of cotton crop was carried out using the hierarchal decision rule-based classification approach. The details of methodology are shown in fig.3.

The area estimation was carried out using multi-date satellite data following the hierarchical decision rule-based classification approach. The crop classification includes two step processing comprising of optimum dates selection covering the all phonological stages of crop and then formation of hierarchical decision rules by using the knowledge base. The hierarchical decision rules were then used for discrimination and classification of the crop. The

Fig. 3: Methodology flow chart.

total area in hectare was computed by multiplying the number of pixels under the crop to the area of each pixel.

Accuracy assessment provides complete information on the categorical accuracy. The area of cotton crop derived from present study is compared with the statistics of Department of Agriculture & Farmers Welfare, Government of Haryana for kharif season 2019. The accuracy assessment of classified mask of cotton crop was also carried out with the help of GT points.

RESULTS AND DISCUSSION

Image Classification

The crop identification, discrimination and acreage estimation using C-band multi-date SAR data and optical data in India was carried out by Ray *et al.*, 2014 and Gosh *et al.*, 2008, 2014. Many experts have also generated radar signatures of cotton and other crops using SAR data (Patnaik *et al.*, 2005, Kumaraperumal, et al. 2017; Liao, 2018; Dave *et al.*, 2019; Oldoni et al., 2020; Nageswara Rao, et al. 2020). For the present study Sentinel-1A, C-band SAR data from May 2019 to September 2019 were acquired. After preprocessing the SAR data, a false color composite was formed by passing the 2 July, 31 August and 24 September images through red, green and blue channels respectively for display. SAR backscatter from crops depends on various plant biophysical parameters. These findings can be verified with the results of Kannan *et al.*, 2021; Krishna *et al.*, 2020; Shang *et al.*, 2020; Jain *et al.*, 2019 and Verma *et al.*, 2019. SAR backscatter values for the cotton and other associated land cover classes on the multi-date data were noted by using ground truth information. The understanding of interaction of large wavelength microwaves with vegetation and knowledge of date of sowing of crops, various crop phenological stages and distribution of crop types within the study area were used to develop a knowledge base. Hierarchical decision rules were formed and used for classification of the land cover classes. Vegetation cover was segregated into cotton and non-cotton classes by using the temporal backscatter response on multi-date data and the cotton crop classified mask was generated. The classified cotton crop mask overlaid on multi-date SAR data are shown in Fig. 4. So, using multi-temporal SAR data, cotton crop can be clearly differentiated from paddy crop and other land use/ land cover classes.

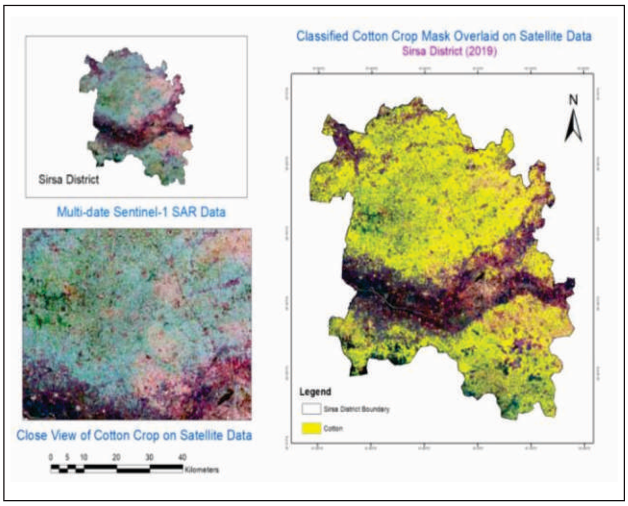

Fig. 4: Classified cotton crop mask.

The area estimation was carried out after generating the classified cotton crop mask following the hierarchical decision rule-based classification approach. The total area in hectare was computed by multiplying the number of pixels under the crop mask to the area of each pixel. The total area of cotton crop as obtained by the analysis is of the multi-date SAR data using hierarchical decision rule-based classification was 152700 ha.

The cotton crop area derived from present study was compared with the area statistics of the cotton acreage released by Department of Agriculture & Farmers Welfare, Government of Haryana for kharif season 2019. These statistics were used for cross-validation of the result obtained in the present study. The relative deviation (RD) of -8.78% is observed which is close to the reality. For accuracy assessment the classified cotton mask was checked with the help of ground truth points using Arc GIS 10.0 software. The overall accuracy of 87.27% was observed. The producer's accuracy for cotton, paddy and other crops was 100%, 88.88% and 20%, respectively. The user's accuracy for cotton, paddy and other crops was 79.31%, 100% and 50%, respectively.

CONCLUSIONS

Analysis of the multi-date satellite data shows that VV polarized C-band Sentinel-1A SAR data is suitable in discriminating cotton crop with other associated kharif crops. The results of the analysis of SAR data indicates that the cotton crop can be discriminated and acreage estimation can be done using the data sets of July (early vegetative stage), August (late vegetative stage) and mid-September (Maturity stage). It was also observed that SAR backscattering from the crop depends on crop biophysical parameters and soil parameters during its various growth and phenological stages. The main stages of cotton crop which directly affect the radar backscattering are land preparation for showing, crop vegetative and boll formation. For fresh sown cotton crop during the month of June, the backscattering mainly depends on the surface of the soil. The soil having high moisture and medium to high roughness will give high backscattering. As the cotton crop grows, radar backscattering further increases up to mid-September due to volume scattering within the crop. However, it was observed that for cotton crop (early and late sown) high backscattering value is observed in September as compared to paddy and other associated kharif season crops. Based on the temporal backscatter profile of cotton crop and other land cover classes, hierarchical decision rules were framed. The hierarchical decision rules were used for classification of the land cover classes. So, the cotton crop is well discriminated from other associated kharif season crops using the optimum date of data sets of July, August and mid-September. Thus, the study also provides the basis of cotton crop identification and area estimation using multi-date VV polarized C-band SAR data. The total area of cotton crop as obtained by the analysis of the multi-date SAR data using hierarchical rule-based classification was 152700ha. The area was compared with the cotton area statistics obtained from the Government Department and the relative deviation (RD) of -8.78% was observed which was close to the reality. The overall accuracy was found 87.27%. These results suggest the scope for using multi-temporal Sentinel-1 VV polarized C-band SAR data to develop an operational cotton crop identification and discrimination framework.

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