Research Article

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International Journal on Agricultural Sciences

International Journal on Agricultural Sciences 13 (1), January-June 2022, pp 26-32
ISSN No.: **0976-450X**

MULTI-TEMPORAL SAR DATA FOR CROP GROWTH MONITORING, AREA ESTIMATION AND ACCURACY ASSESSMENT OF PADDY CROP IN SIRSA DISTRICT, HARYANA, INDIA

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Received: **23.02.2022** Revised: **08.06.2022** Accepted: **09.06.2022**

ABSTRACT

Agriculture is the mainstay of Indian economy. India is second largest population country in the world whose demand of food is sustained by agriculture. Geo-informatics plays a vital role in management of agricultural activities on sustainable basis. The estimation of crops during kharif season becomes difficult due to non- availability of optical satellite data in cloud cover at required stage. A Synthetic Aperture Radar (SAR) system operating in the microwave region of the electromagnetic spectrum has an ability of imaging the earth surface day and night even during cloudy weather. The present study was carried out for identification and area estimation of paddy crop using multi-date Sentinel-1 SAR data (C-band) for Sirsa district of Haryana. Multi-date SAR images for the months of June 2020 to September 2020 covering all main phenological stages of crop were acquired. SAR backscatter values for paddy and other associated major kharif season crops were noted on multi-date SAR data. The rule-based classification approach was used for monitoring and identification of paddy 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 paddy crop during kharif season. The total area of paddy crop as obtained by the analysis of the multi-date SAR data using hierarchical decision rule-based classification was 52917 ha. The overall accuracy and Kappa coefficient were found 94.27% and 88.46% respectively. These results suggest the scope for using multi-temporal Sentinel-1A VV polarized C-band SAR data to develop an operational paddy crop identification and estimation framework during Kharif season when the optical satellite data is difficult to obtain due to cloud cover.

Keywords: Sentinel-1, SAR, backscattering, paddy, Sirsa, Haryana.

INTRODUCTION

Agricultural resources are important renewable natural resources. These sustain the livelihood of about 70 percent of Indian population and are the backbone of Indian economy. Besides providing food security agriculture also provides employment opportunities to a large proportion of the population in the country.

India is the second largest producer of paddy in the world while has the largest area under cultivation. In Haryana state paddy is the important food crop grown during the kharif season. This crop is grown in rain fed areas which receive minimum annual rainfall of more than 100 cm. The crop is mainly grown during the monsoon season. In this season the cloud cover restricts the operational use of the optical sensors especially in the paddy growing season (June-September). Synthetic Aperture Radar (SAR) being an active remote sensing system operates in the microwave region of the electromagnetic spectrum having the wavelength ranging from 1mm to 1m. Due to its 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. Krishna et al. (2020) conducted a study

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on paddy crop classification using microwave satellite data.

The high temporal resolution of Sentinel-1A also allows assessing the crop growth and crop discrimination. The characteristic of C-band SAR data enables applications in agriculture for the kharif season. Sensitivity of SAR data to crop geometry, crop structure and moisture content can be suitably exploited for the crop discrimination. Subbarao et al. (2021) used multi date Sentinel-1 SAR data for identification of paddy crop in Bhandara district. The results of the various studies indicate that as the crop grows, backscattering increases due to the volume scattering from the crop. So, it is observed that multi-date SAR data is very useful for crop growth monitoring and area estimation of various crops.

STUDY AREA

The study area Sirsa district lies in the extreme west corner of Haryana State and lies between 29º14′ N to 29°59′ N latitudes and 74°27′Eto 75°18′ E longitudes covering an area of 4277 sq. km. **(Fig.1)**. It is surrounded by Faridkot and Bhatinda districts of Punjab in the north and north-east, Ganganagar and Hanumangarh districts of Rajasthan in the west and south and Fatehabad district of Haryana in the east. The average annual rainfall in the district is 222.72 mm and over 83% is received during the months of June to September. Rainfall is also received during the winter months of December to February due to western disturbances.

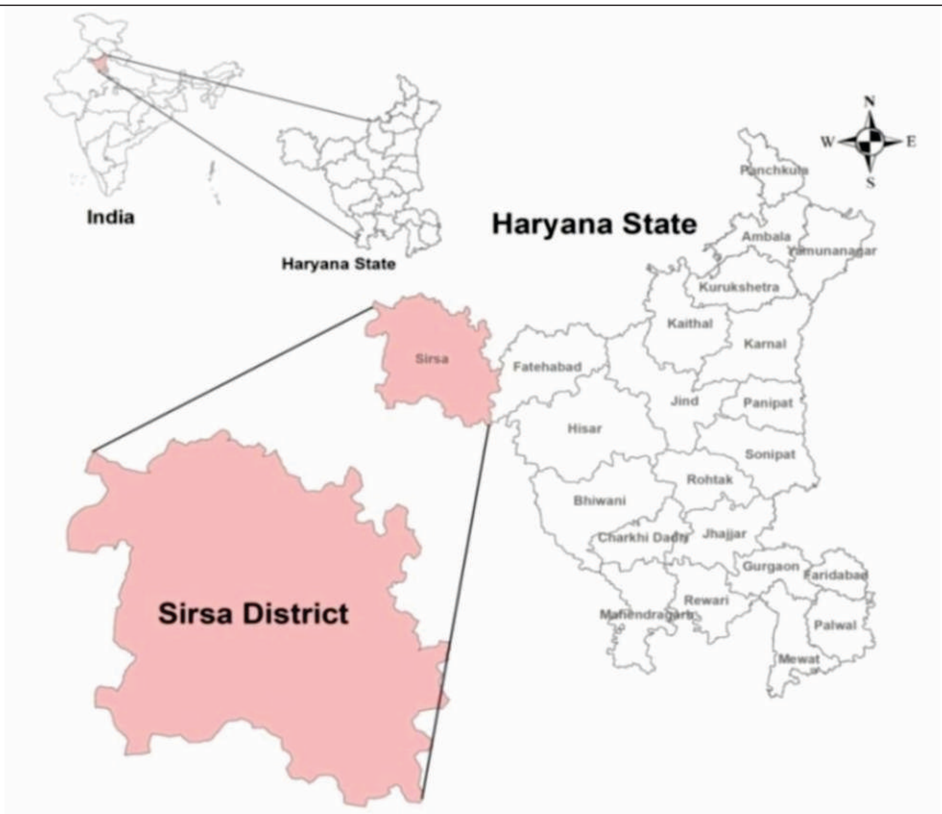

Fig.1: Location map of study area.

The district is covered mainly by three soil orders i.e. Entisols, Inceptisols and Aridisols. The major part of the district is occupied by Typic Comborthids and Typic Torripsamments soils but VerticHeplustepts and Typic Ustifluvents are also found in low lying areas. Soil texture in major parts of the district varies from loamy sand to sandy loam but loam to clay loam texture is also found in low lying areas. Wheat, mustard and gram are the major rabi season crops whereas rice, cotton and bajra are kharif season crops in the study area.

MATERIALS AND METHODS

Data used

Multi-date Sentinei-1A SAR data was used for the estimation of paddy in the study area (Table 1). This data was downloaded from the Copernicus website from June 2020 to September 2020 (Table 2).Sentinel-1A having C band Synthetic Aperture Radar (SAR) provides all weather day and night data at temporal resolution of 12 days and it has four different operational modes-Interferometric Wide Swath (IW), Wave (WV), Strip map (SM) and Extra Wide

Swath (EW). In this study high resolution Level-1 IW Ground Range Detected (GRD) VV polarized multi-date images have been used.

The ground truth points was collected by the state Agriculture Department officials using a Smartphone-based Android App, called Bhuvan FASAL developed by National Remote Sensing Centre (NRSC), ISRO, Hyderabad. The ground truth data includes location in the form of latitude and longitude, field photographs and field parameters which are uploaded to Bhuvan Portal. This data was used to classify the satellite data for identification of paddy in the district after downloading from Bhuvan portal. Fig. 2 shows ground truth points overlaid on the satellite imagery of Sirsa district.

Table 1: Specifications of Sentinel-1 satellite data.

Attribute	Value
Frequency	5.405 GHz
Polarization	HH/VV/HV/VH/HH+HV/VV+VH
Mode	SM/IW/EW/WV
Product Type	SLC/GRD/OCN
Resolution	20*20
Ground Range	250 km
Repetivity	12 days
Order By	Descending/Ascending

Table 2: Details of multi-temporal dates acquired for analysis.

S. No.	Acquisition Date
1.	08 June, 2020
2.	02 July, 2020
3.	26 July, 2020
4.	31 August, 2020
5.	12 September, 2020
6.	24 September, 2020

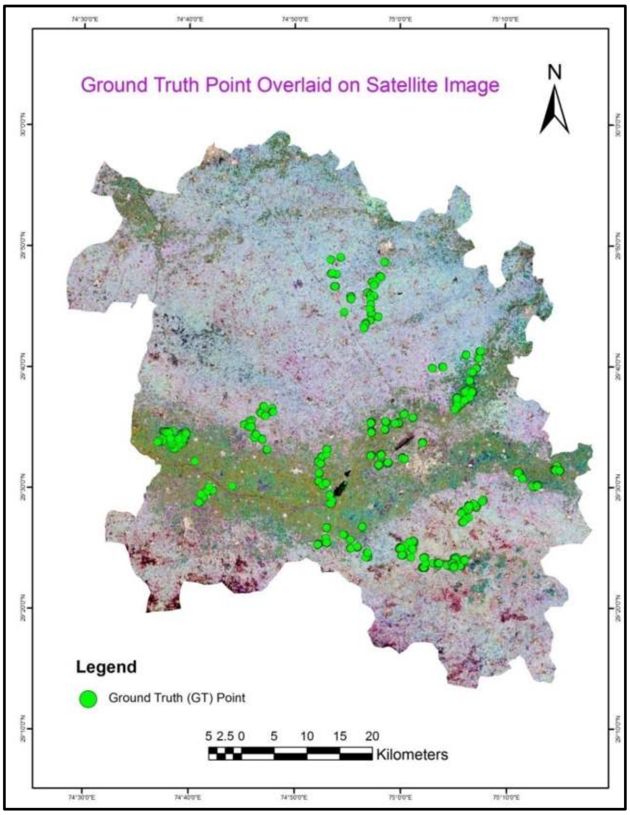

Fig. 2: Ground truth point overlaid on satellite image.

Methodology

The SAR multi-date data from June to September 2020 was downloaded and pre-processed by following the standard procedure of apply orbit file, calibration, multi looking, speckle filtering and terrain correction. The multi-date pre-processed images were co- registered, and a data stack was formed covering all the acquisitions. Using ground truth (GT) points, temporal radar backscatter values were noted for the paddy, other associated kharif season crops and various land cover features from multi-date stack layers. Each crop has a different date of sowing and growing pattern also having differences in crop biomass, moisture content, plant height, plant density per meter square. Due to variation in these characteristics, a significant difference in radar 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, etc. of paddy crop and hierarchical decision rules were formed. The analysis and identification of paddy 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 phenological stages of crop and then formation of hierarchical decision rules by using the knowledge base. The hierarchical decision rules were then used for identification and classification of the crop. The 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 accuracy assessment of classified mask of paddy crop was also carried out with the help of ground truth (GT) points.

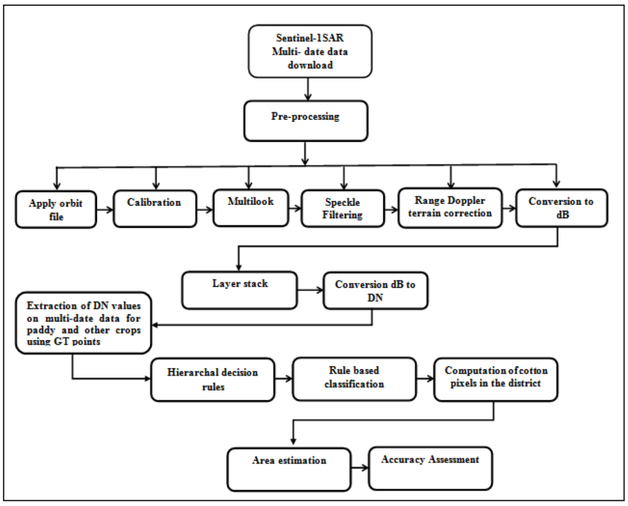

Fig. 3: Methodology flow chart.

RESULTS AND DISCUSSION

SAR Signature Analysis

SAR backscatter from the crops depends on various crop biophysical parameters and soil parameters during its various growth and phenological stages. The increase in radar backscattering with change in crop structure and crop biomass due to the effect of volume scattering have been reported by many authors (Chakraborty et al.(2005); Macelloni et al. (2001); Moran et al. (1997); Shao et al.(2001); Jia et al.(2012) and Haldar et al. (2011).The paddy crop has sowing period starting from mid-June up to last week of July and requires a lot of water, thus, paddy fields are flooded with water at the time of transplanting of crop. It is transplanted on the flooded water, so very low backscattering is observed from the transplanted paddy fields in June and July. This may be due to the specular reflectance. The specular reflectance occurs from the flat surface like smooth playground and flooded water, etc. In this case most of the radar energy is reflected away from the sensor resulting in low backscattering. As the paddy crop grows and attains its vegetative stage the canopy cover, crop biomass and leaf area increase. This results in presence of multiple scatters within the crop. This will change the scattering behavior and intensity of energy returned back to the SAR antenna. The backscattering increases due to double bounce and volume scattering from the crop. In the September the backscattering gets saturated and after that no considerable increase in backscattering is observed. This may be as near the harvesting stage, the moisture content within the crop is decreased resulting in reduced and saturated backscattering values.

Image Classification

The crop identification, discrimination and acreage estimation using C-band multi-date SAR data and optical data in India was also carried out by Ray *et al.*, 2014 and Gosh *et al.*, 2008, 2014. Many experts have also generated radar signatures of crops using SAR data (Dave *et al.*, 2019 and Patnaik *et al.*, 2005). For the present study, Sentinel-1C-band SAR data from June 2020 to September 2020 was acquired. 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 paddy 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 district 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 the paddy and non-paddy classes by using the temporal backscatter response on multi-date data and the paddy crop classified mask was generated. Fig. 4 shows the classified paddy crop map of the study area.

Area Estimation

The area estimation was carried out after generating the classified paddy 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 paddy crop as obtained by the analysis of the multi-date SAR data using hierarchical rule-based classification was 52917 ha.

Accuracy Assessment

For accuracy assessment, the classified paddy mask was checked with the help of ground truth points using Arc GIS

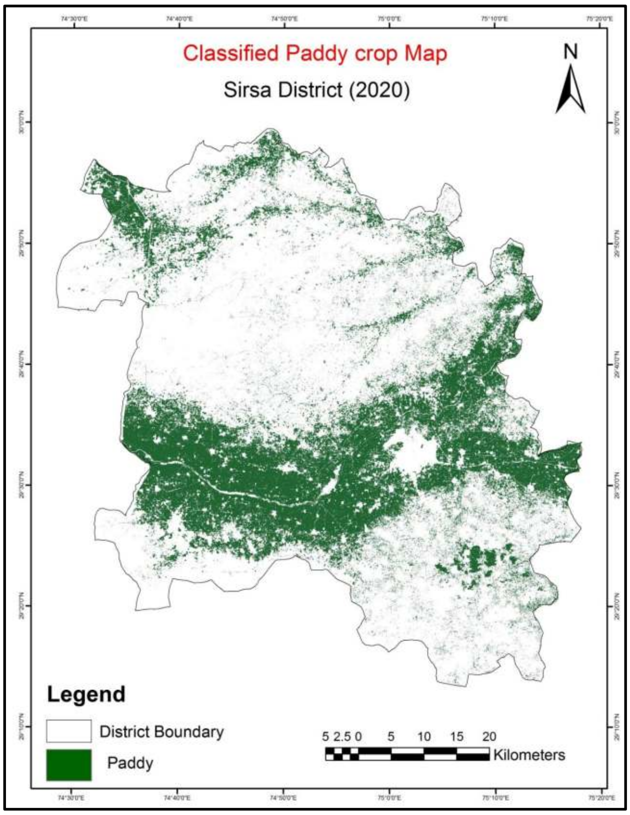

Fig. 4: Classified paddy crop map.

10.0 software. The user's accuracy is defined as the probability that a pixel classified on the image actually signifies that category on the ground and the producer's accuracy is defined as the probability that any pixel in the category has been correctly classified. In the Omission error off-diagonal row elements represent ground truth pixels of a certain class which were excluded from that class during classification and in the commission off-diagonal column elements represent ground truth pixels of other classes that were included in a certain classification class. Overall accuracy is the number of correctly classified pixels of diagonal elements divided by the total number of accuracy pixels. In the Kappa coefficient off-diagonal elements are incorporated as a product of the row and column marginal totals. It is a discrete multivariate technique used to assess classification accuracy from an error matrix. Kappa analysis generates a statistical test to evaluate the accuracy of a classification. Kappa evaluate how well the classification performed as compare to just randomly assigning value. The user's and the producer's accuracy, Omission and Commission error, the overall accuracy and Kappa coefficient are calculated as given below:

User's accuracy = Total number of correct pixels in a category / Total number of pixels of that category derived from the reference data (column total) * 100

Producer's accuracy = Total number of correct pixels in a category / Total number of pixels of that category derived from the reference data (row total) * 100

Omission error = Sum of off-diagonal row elements / row total*100

Commission error = Sum of off-diagonal column elements / column total*100

Overall accuracy = Sum of the diagonal elements / Total number of accuracy pixels *100

Kappa coefficient = Observed Accuracy - Expected accuracy / 1 - Expected accuracy * 100

The overall accuracy and Kappa coefficient were found 94.27% and 88.46% respectively. The producer's accuracy, user's accuracy, Omission error and Commission error was 94.61%, 94.87%, 5.13% and 5.41% respectively.

Table 3: Accuracy assessment.

Pixels	Paddy	Other Crops	Row Total	Users Accuracy (%)	Omission Error (%)	Commission Error (%)
Paddy	3071	166	3237	94.87	5.13	5.41
Other crops	175	2544	2719	93.56	6.44	6.11
Column Total	3246	2710	5956			
Producers Accuracy	(%)	94.61	93.87			

Overall Accuracy: 94.27%; Kappa Coefficient: 88.46%

CONCLUSIONS

Analysis of the multi-date satellite data shows that VV polarized C-band Sentinel-1 SAR data is suitable for identification and area estimation of paddy crop. The results of the analysis of SAR data indicates that the paddy crop can be identified 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. In case of paddy crop, land preparation for showing, crop vegetative and boll formation are the main stages which directly affect the radar backscattering. Based on the temporal backscatter profile of paddy 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 paddy crop is well discriminated from the 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 paddy crop identification and area estimation using multi-date VV polarized C-band SAR data. The total area of paddy crop as obtained by the analysis of the multi-date SAR data using hierarchical rule-based classification was 52917 ha. The overall accuracy was found 94.27%. These results suggest the scope for using multi-temporal Sentinel-1 VV polarized C-band SAR data to develop an operational paddy crop identification and growth monitoring framework.

ACKNOWLEDGEMENTS
Authors are grateful to Director, NRSC, Hyderabad for providing ground truth points and sincerely thank Director, HARSAC, Hisar for providing the necessary facilities for carrying out the present study. We thank the Copernicus Open Access Hub for allowing free downloading of Sentinel-1 multi-temporal SAR data.

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