# Kharif Crop-Type Mapping of Haryana State using Geospatial Approach

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**Abstract**
Crop type and acreage is essential information for food security and management. Remote sensing is a reliable and efficient method of obtaining necessary information on crop type and acreage. This study focuses on the crop classification and crop acreage using the both optical and microwave (SAR) data from Sentinel platform for the kharif 2022 by spectral reflectance values of optical data and back scattering values of Synthetic-aperture radar (SAR) data in 22 districts of Haryana. The unsupervised k-mean classification techniques have been used for optical and microwave data. The temporal spectral profile of optical data exhibited distinctive spectral pattern for Paddy, Bajra, Sugarcane, Cotton, Jowar, and Maize during July 2022 to September 2022. Simultaneously, the SAR data indicated variation in the backscatter of crops i.e., -21.80 to −18.05 dB (VH) & -13.12 to -09.00 dB (VV) for paddy, -20.00 to −17.30 dB (VH) & -11.12 to -9.27 dB (VV) for bajra, -17.10 to −13.30 dB (VH) & -08.84 to -07.14 dB (VV) for sugarcane, -19.20 to −13.10 dB (VH) & -06.79 to -5.75 dB (VV) for cotton, -17.09 to −16.03 dB (VH) & -8.36 to -4.39dB (VV) for maize, -17.77 to −16.67 dB (VH) & -11.17 to -9.67dB (VV) for jowar and during kharif crops. The classification results show that there is very high accuracy of optical classified data for the paddy, cotton, bajra i.e. 90.67%, 70.91% & 69.83% respectively while in the classified SAR data the accuracy is 84.73%, 73.97% and 66.5% in the paddy, bajra and cotton respectively. At a larger scale the accuracy achieved show potential of SAR data for the mapping of Kharif crops which may be used for crop yield assessment in cloud scenario of optical data.

**Key Words** Synthetic Aperture Radar, Optical Satellite Data, Unsupervised Classification, Spectral Signature, backscatter

## Introduction

Agriculture holds immense importance in Indian society. It has an impact in the economy, employment, food security, national self-reliance, and general well-being (Dadhwal et.al 2002). Agriculture abstract 2022, Haryana has recently experienced industrial development, and most of its economy is still based on agriculture. Agriculture is the primary occupation of about 70% of residents. In terms of the nation's production of food grains, Haryana comes in second. Haryana produces enough food for itself and is the second-largest provider for India's main supply of grains. About 96% of the territory is arable, and of that, 86% is used for agriculture. Through the use of substantial canal infrastructure and tube wells, almost 75% of the region is irrigated. Haryana made a big contribution to India's Green Revolution in the 1970s, which made the nation's food self-sufficient (https://haryana.pscnotes.com). Haryana, despite its small size, has made significant contributions to agriculture, achieving the highest productivity in India for crops like wheat, mustard, sugarcane, and vegetables during the rabi season, and crops like bajra, sugarcane, cotton, groundnut, maize, and paddy during the kharif season. Major crops in Haryana's 22 districts include paddy, wheat, sugarcane, and bajra. Other crops like moong, barley, oilseeds (such as sarson, toria, and tarmira/tira), and vegetables (like radish, turnip, carrot, Palak, methi, cabbage during kharif season) are also cultivated. Fruits grown in the state include malta-orange, sweetlime, mango, guava, ber, pomegranate, grape, and phalsa. Satellite imagery plays a crucial role in identifying the mapping of croplands, crop types, and providing timely, cost-effective, and precise information using satellite data (M.P. Sharma 2014). This technology is invaluable for agricultural planning and resource management at local, regional, and global levels. Cropland distribution changes are mapped and monitored to give information that supports sustainable agricultural practices and early warning of potential challenges to regional and global food security (McNairn et al., 2009). Several authors have demonstrated the usefulness of satellite data for analyzing cropping patterns and the use of remotely sensed imagery in agriculture (Li et al., 2020; Osama et al., 2017; Liu et al., 2018; Lobell et al., 2013). It provides reliable information on agricultural activities, including identifying and classifying various crops and it provides accurate details about agricultural activities like diverse cropping patterns, crop condition monitoring, crop growth, and crop acreage (Vibhute et al., 2013). It is observed that most of the research relied heavily on ground data, were exploratory investigations, tested locally, and employed only one kind of remote sensing sensor (Bégué et al., 2018). Using field observation to analyze cropping patterns is time-consuming, so we can analyze them more efficiently with satellite imagery (Bhumika et. al. 2019). Discrimination of major kharif crops is based on spectral-temporal signatures (Hierarchical/Two-stage ISODATA clustering). For homogeneous patches of crops the unsupervised classification is found suitable, pixels with similar spectral characteristics are automatically grouped into unique clusters based on some statistical criteria. The production of land cover maps uses a variety of classification techniques that have been created and are now in use (Al-Doski et al., 2013). Spectral profile of both optical and microwave data has the capability to classify a variety of crops.

Using field observation to analyze cropping patterns is time-consuming, so we can analyze them more efficiently with satellite imagery (Bhumika et. al. 2019). Discrimination of major kharif crops is based on spectral-temporal signatures (K-mean clustering). Several remote sensing techniques are employed for continuous monitoring and analysis of agricultural crops, including optical, microwave, thermal, and hyper-spectral remote sensing. Specifically, Sentinel-1 (SAR) datasets and Sentinel-2 datasets sourced from the Alaska Satellite Facility & Copernicus Open Access Centre are utilized for crop classification (Tavus et al., 2021). In the pre-processing stage, Sentinel Application Platform (SNAP) Software is employed to work with Sentinel-1 SAR data. SNAP is utilized to minimize errors in SAR data by applying algorithms provided within the Sentinel Applications Platform (SNAP) package, which is made available by the European Space Agency (ESA) for the real SAR data pre-processing phases. This software aids in enhancing the quality and accuracy of the SAR data used in crop mapping and analysis (Vollrath et al., 2013). In the post-processing phase, SAR data for the 22 districts of Haryana state is handled within a geo-spatial platform. On the other hand, for optical data, both pre-processing and post-processing are conducted using ArcGIS 10.8. These geo-spatial software tools assist in the refinement and analysis of optical data, enhancing the accuracy and reliability of the crop mapping and analysis conducted in the study.

*Objectives:*
The current study has specific objective including crop type mapping of Haryana state using the optical & microwave data.

- To do a Comparative analysis of Haryana state through the SAR & optical satellite data.
- To calculate the crop acreage on the best result of accuracy assessment.

## Materials and Methods

*Study Area:* Haryana is a state located in northwest India, covering an area of 44,212 square kilometres. Geographically, it falls between 27°39' and 30°35' north latitudes and 74°28' and 77°36' east longitudes. It shares its borders with Punjab and the union territory of Chandigarh to the northwest, Himachal Pradesh and Uttarakhand to the north and northeast, Uttar Pradesh and the union territory of Delhi to the east, and Rajasthan to the south and southwest. The location map of the study area on satellite image is shown in Fig. 1.

For administrative purposes, the state is divided into six divisions (Ambala, Rohtak, Gurgaon, Hisar, Karnal and Faridabad) and 22 districts. The four main geographical features are Shivalik Hills, Ghaggar Yamuna Plain, Semi-desert sandy plain, and Aravali hills. Haryana's crops are categorized into Kharif and Rabi crops, with cotton, paddy, and bajra being the main Kharif crops, grown from July to Oct, and mustard, wheat, and sunflower as the principal Rabi crops grown during Nov. to April. The northwestern part of the state is conducive to rice, wheat, vegetables, and seasonal fruits, while the southwestern region is suitable for high-quality agricultural produce, tropical fruits, exotic vegetables, as well as herbal and medicinal plants (https://farmech.dac.gov.in/FarmerGuide/HR/index1.html).

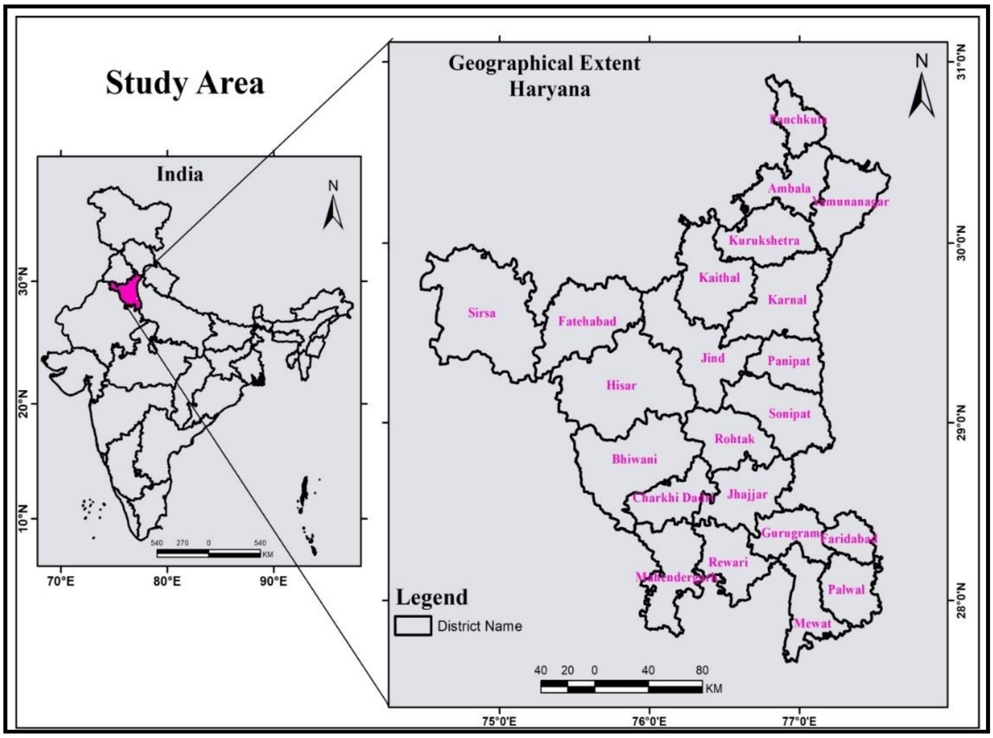


**Fig. 1** Location map of study area.

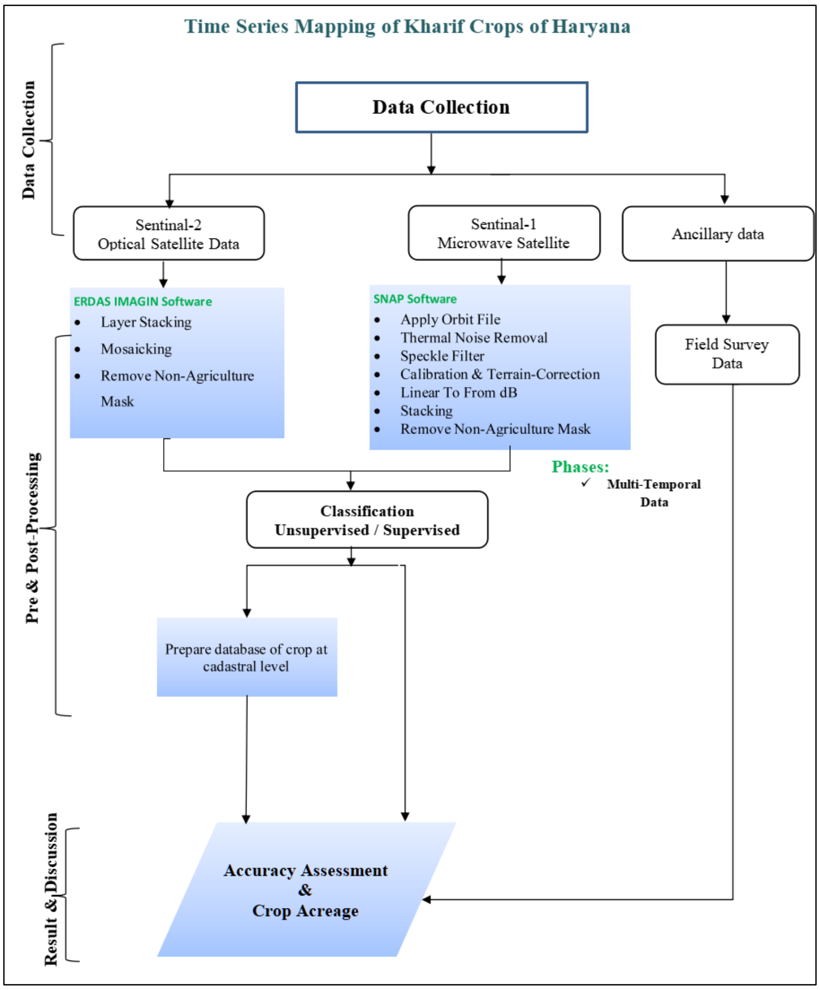


**Fig. 2:** Workflow of Time Series Mapping of Kharif crops.

*Methodology:*

The methodology adopted for this study is given below as flow chart (Fig. 2). The methodology of the study is divided into three sections. First section describes the data collection and preparation. The second section includes pre & post processing of both optical and microwave data. Third section includes the Accuracy Assessment using field survey (GT points) data which was done through a mobile based application.

*Data Requirements:* High resolution optical and microwave data was used for the extraction of information on various kharif crops. Ground data was used for the cluster naming.

*Ground Data:* Ground data was collected through the field survey and the GT points were collected with the help of mobile application. These GT points were utilised to prepare the Kharif crop type distribution map which was represented in Figure 3. A total of 2,01,794 sample locations were collected during the field survey of the Kharif season. Out of these, 1,22,179 samples across all 22 districts of Haryana were dedicated to the class assignment of both optical and microwave remote sensing data. The remaining 79,615 points were reserved for district-wise accuracy assessment of the classified data.

*Satellite Data:* SAR data was obtained from https://search.asf.alaska.edu/ while optical data was downloaded from the https://scihub.copernicus.eu/. The Specification of SAR and optical data is depicted in Table.1.

**Table 1** Specifications of microwave and optical remote sensing Data.

| S. No | Parameters | Data Specification | | | |
|---|---|---|---|---|---|
| | | Microwave | | | Optical |
| 1 | Satellite | Sentinel-1 | | | Sentinel-2 |
| 2 | Resolution | 10x10 m Spatial Resolution | | | 10x10 m Spatial Resolution |
| 3 | Polarization | VV & VH Band | | | Nir, Red, Green & SWIR Band |
| 4 | Beam mode | IW- Interferometric Wide swath | | | MSI |
| 5 | Flight Direction | Ascending | | | Descending |
| 6 | Band | C | | | Level-1C |
| 7 | File type | L1 Detected High-Res Dual-Pol (GRD-HD) | | | S2 A |
| 8 | Date of Satellite Image | Path | Frame | Absolute Orbit | |
| a. | 09-July-2022 | 27 | 92 | 44024 | |
| b. | 09-July-2022 | 27 | 97 | 44024 | 27-Aug-2022 |
| c. | 21-July-2022 | 27 | 92 | 44199 | |
| d. | 21-July-2022 | 27 | 97 | 44199 | |
| e. | 02-Aug2022 | 27 | 92 | 44374 | |
| f. | 02-Aug-2022 | 27 | 97 | 44374 | |
| g. | 14-Aug-2022 | 27 | 92 | 44549 | |
| h. | 14-Aug-2022 | 27 | 97 | 44549 | |
| i. | 26-Aug-2022 | 27 | 92 | 44724 | |
| j. | 26-Aug-2022 | 27 | 97 | 44724 | |

(**Source:** https://search.asf.alaska.edu/ & https://scihub.copernicus.eu/)

*Crop Classification:* The use of remote sensing information for crop classification has existed for a long time (Ennouri et al. 2019). Analysis of large time series satellite data for providing clear crop type information which is used for by the decision maker (Rembold et.al 2015). The complete cloud free scenes are essential in optical data classification. Due to the difficulty of getting the cloud free scenes during the Kharif season, microwave data could be used because of its all-weather capability. The individual scenes are stacked for the district-wise classification. Unsupervised classification methods were utilized for time series mapping of Kharif crops. This involves the automatic identification and assignment of image pixels to spectral groups. Time series SAR images with two bands (VV & VH) and Sentinel-2 optical images (10m resolution) with three bands (NIR, RED and GREEN) were stacked separately for the Kharif crop classification. A non-agriculture mask was employed to remove the non-agricultural areas from both optical and microwave satellite data in order to improve the results. Spectral signatures of crops were determined based on ground truth regions and satellite data.

## Result & Discussion

*Dominance Crop during Kharif 2022:* The field survey map of the Kharif crop type which was prepared using the GT points has given below (Fig. 3).

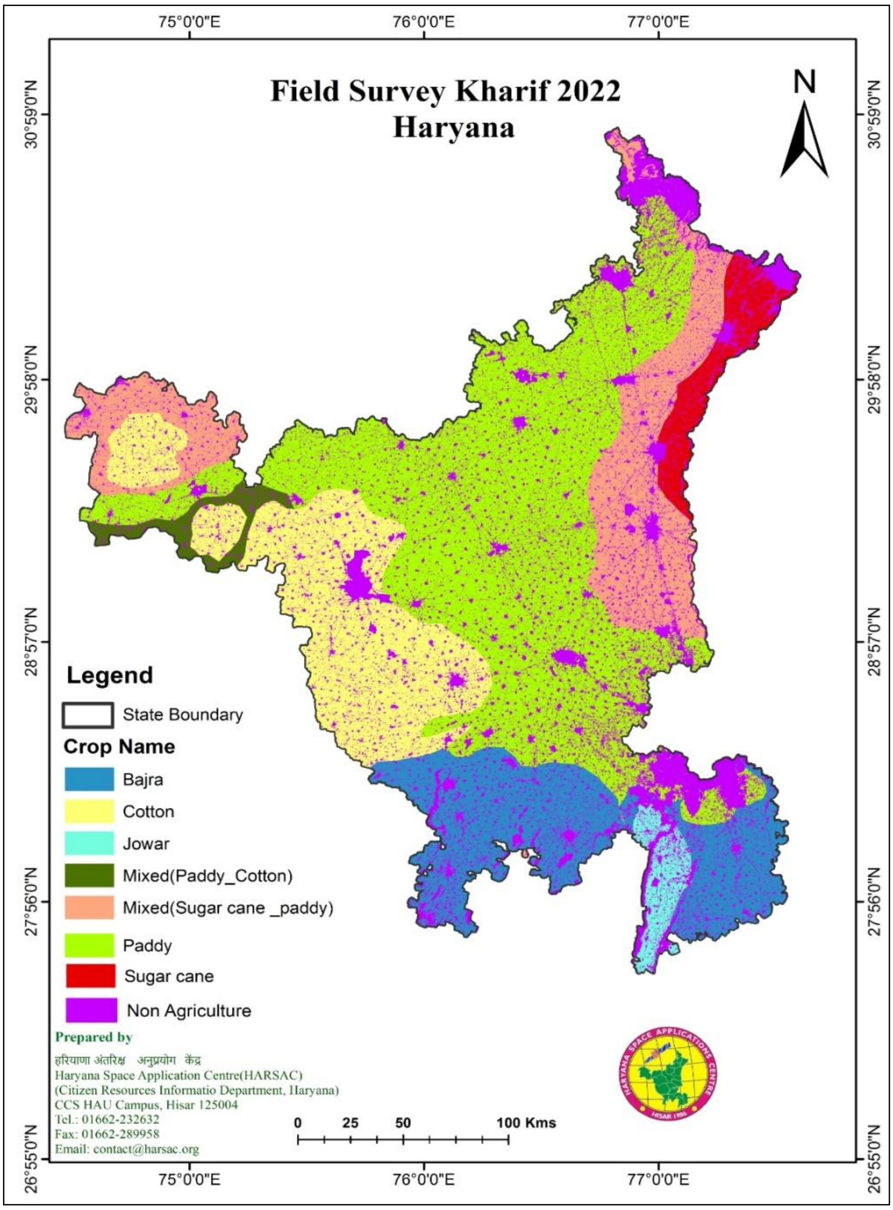


**Fig. 3** Field Survey crop type map of study area.

The figure shows the crop dominance during Kharif season 2022. This map is the first of its kind which may provide a base for further crop classification. The southern part of the state showed the dominance of Bajra and Jowar. The western part was mostly dominated by Cotton and cotton mixed with paddy. Sugarcane dominated in the eastern parts of the state following the Yamuna course. The central and Northern parts were dominated by Paddy and Paddy mixed with other crops.

*Spectral Discrimination of Crops:* The crop calendar in India varies based on regions and crops. Notably, back-scattering values in both VH and VV bands increased as crops reached the harvesting stage. Reflectance values of the four band Blue, Green, Red & NIR are presented in Figure.5 whereas, spectral values of the VH & VV band are presented in Figure 4.

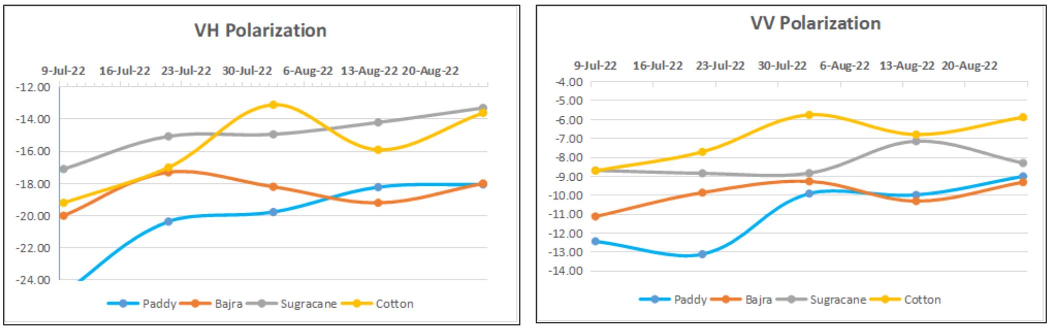


**Fig. 4** Back scattering values of both VV & VH bands of SAR data for major crops Haryana.

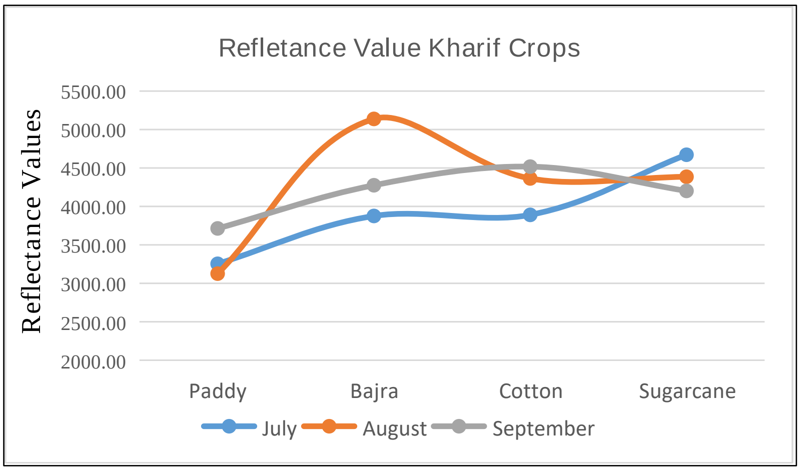


**Fig. 5** Reflectance value of Sentinel-2 satellite data.

In Haryana, rice is primarily grown during the kharif season from June to October, while cotton is sown in July to November during the same season. Sugarcane, on the other hand, is cultivated from December to March. It's worth noting that even within a district, there can be differences in crop sowing times, including both early and late sowing practices.

*Crop type mapping:* The use of satellite remote sensing for crop monitoring offers the advantage of comprehensive coverage, both spatially and temporally. Timely information on crop growth and development has become more accessible due to improvements in remote sensing imagery resolutions (spectral, spatial, radiometric, and temporal). Microwave data collection, on the other hand, relies on backscratching values. An app-based survey captures ground truthing points from various locations throughout the district, fixing each crop's signature for unsupervised classification. Figure.6 and Figure.7 display crop type for the kharif season in Haryana. The results revealed that paddy, cotton, bajra, sugarcane, jowar, and bajra were predominant kharif crops in the Haryana state.

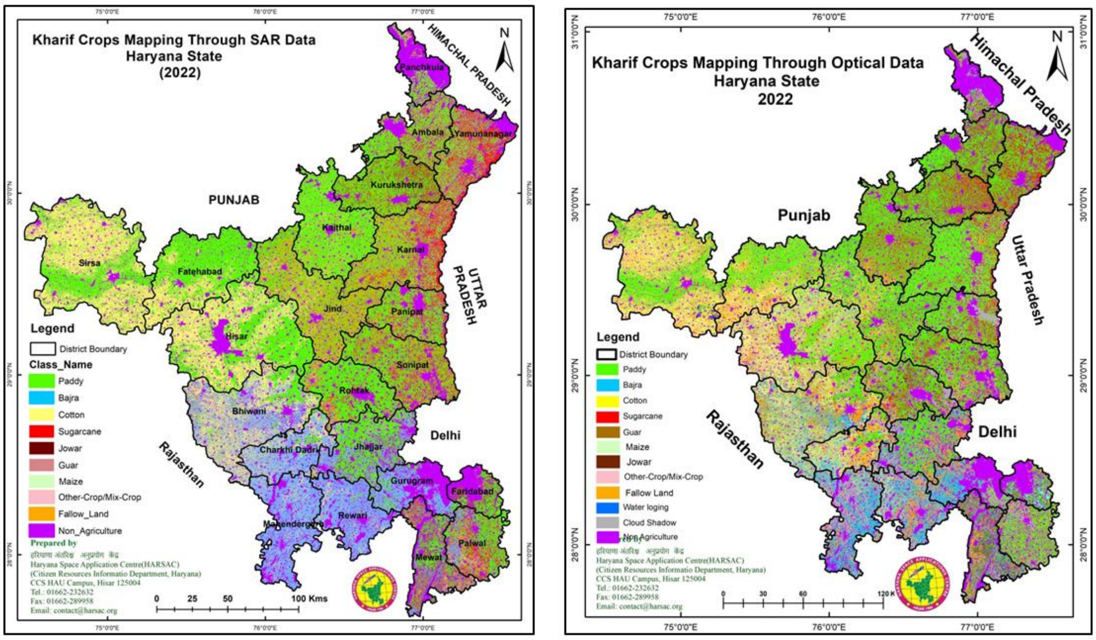


**Fig. 6 (left) & 7 (right) Layout Map of the Microwave Classified Data and Optical Classified Data.**

*Comparative Accuracy Assessment:* The accuracy of each crop was calculated for both optical and microwave satellite data by comparing the output to ground truth data and presented in Table 2. It was clear from the table that the overall crop accuracy was high (79.90%) for the classified optical data, while comparatively lower for SAR data (65.06%), When considering the accuracy of specific crops, similar trend was followed for paddy, cotton, sugarcane, and bajra. The accuracy was very high for optical classified data of paddy, cotton, and bajra i.e. 90.67%, 70.91% & 69.83% respectively while in the classified SAR data the accuracy was a little bit low as 84.73%, 66.5% and 73.97% for the paddy, cotton, and bajra respectively.

**Table 2** Crop-wise accuracy assessment of both optical & microwave classified satellite data.

| | Accuracy Assessment in % | |
|---|---|---|
| Crop Name | Optical | Microwave |
| Paddy | 90.67 | 84.73 |
| Bajra | 69.83 | 73.97 |
| Cotton | 70.91 | 66.51 |
| Maize | 7.55 | 3.11 |
| Sugarcane | 65.52 | 45.28 |
| Jowar | 41.82 | 26.95 |
| Guar | 58.82 | 5.13 |
| Other Crop | 30.22 | 5.96 |
| Overall Accuracy | 79.90 % | 65.06 % |

*Crop acreage Estimation:* The results of crop acreage estimation of Haryana state through the optical data are presented in Table 3.

The table conveys that the area of paddy accounts highest during the Kharif season for about 33.78 % of the total geographical area followed by cotton and bajra which are 13.42% and 9.0 % respectively. Maize occupied the least area (0.02%) during the season

Because of the comparatively higher accuracy of the optical classified data over the SAR data, the crop acreage of Haryana state was calculated on the basis of optical satellite data.

**Table. 3** Crop-wise area acreage through the optical satellite data

| Crop Name | Kharif (2022) Crop Area Total Geographical Area of Haryana | Optical Kharif (2022) Crop Area in % |
|---|---|---|
| Paddy | 10925023.1 Acre | 33.78 % |
| Bajra | | 9.00 % |
| Cotton | | 13.42 % |
| Maize | | 0.02 % |
| Sugarcane | | 3.89 % |
| Jowar | | 1.54 % |
| Guar | | 0.27 % |
| Other Crop | | 3.40 % |
| Fellow Land | | 9.56 % |

## Conclusion

The present study was focused on estimating acreage of crops and assessing accuracy of SAR and optical data during the Kharif season in Haryana. SAR data is particularly valuable during the monsoon season when optical data may be limited due to cloud cover.

- The Accuracy of optical data is good compared to microwave.
- Crop typing for whole state were possible using remote sensing and ground survey data.
- The crop dominance map is developed first in the state taking the ground data as reference. This map is valuable input for the further classification of crops using satellite data.
- The overall accuracy of the crop map was ≃80% obtained from optical data and independent 80000 reference GT points.
- For paddy dominated areas the SAR data provided comparative results, hence the same must be used for the Kharif season which is affected by cloud cover.
- Minor crops and areas with diverse crops are having issues in the classification accuracy and need further investigation.
- Major Kharif crop of year 2022 were Paddy, Cotton, Bajra, and Sugarcane.
- Paddy was the major crop in the state and mainly distributed in central and northern part of it.
- The crop assessment in Haryana has the potential to provide valuable information for a wide range of stakeholders, contributing to more efficient and sustainable agricultural practices and better-informed decision-making. Extending the time frame

of SAR image acquisition further could enhance the study's accuracy and usefulness for these purposes.

However, there are opportunities to enhance the accuracy of this study by extending the time frame of SAR image acquisition into August and September. The study's findings have various potential applications, including: Crop Pattern Analysis, Planning and Management, Crop Clustering, Benefit for Farmers, and Government Officials.

**Acknowledgements**

Authors would like to thank and acknowledge the Haryana State Agricultural Marketing Board (HSAMB) for the funds and support rendered throughout in carrying out the project. Sentinel-Hub is acknowledged for the Visualization, Author thanks HARSAC for lab facility.

**References**

Al-Doski, J., Mansor, S. B., & Shafri, H. Z. M. (2013). NDVI differencing and post-classification to detect vegetation changes in Halabja City, Iraq. *IOSR Journal of Applied Geology and Geophysics*, *1*(2), 01-10.

Backhaus, A., Bollenbeck, F., & Seiffert, U. (2011, June). Robust classification of the nutrition state in crop plants by hyperspectral imaging and artificial neural networks. In 2011 3rd Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS) (pp. 1-4). IEEE.

Bégué, A., Arvor, D., Bellon, B., Betbeder, J., De Abelleyra, D., PD Ferraz, R., & R. Verón, S. (2018). Remote sensing and cropping practices: A review. *Remote Sensing*, *10*(1), 99.

Bhumika, K., Vadher, B. M., & Agnihotri, P. G. (2019). Application of remote sensing and GIS in cropping pattern mapping: a case study of Olpad Taluka, Surat. In *Conference paper: Emerging Research and Innovations in Civil Engineering* (Vol. 4, No. 9, pp. 343-348).

Dadhwal, V. K., Singh, R. P., Dutta, S., & Parihar, J. S. (2002). Remote sensing-based crop inventory: A review of Indian experience. Tropical Ecology, 43(1), 107-122.

Ennouri, K., & Kallel, A. (2019). Remote sensing: an advanced technique for crop condition assessment. *Mathematical Problems in Engineering*, *2019*.

Li, R., Lv, F., Yang, L., Liu, F., Liu, R., & Dong, G. (2020). Spatial–temporal variation of cropping patterns in relation to climate change in Neolithic China. *Atmosphere*, *11*(7), 677.

Lobell, D. B. (2013). The use of satellite data for crop yield gap analysis. *Field Crops Research*, *143*, 56-64.

McNairn, H., & Shang, J. (2016). A review of multitemporal synthetic aperture radar (SAR) for crop monitoring. *Multitemporal remote sensing*, 317-340.

Osama, S., Elkholy, M., & Kansoh, R. M. (2017). Optimization of the cropping pattern in Egypt. *Alexandria Engineering Journal*, *56*(4), 557-566.

Rembold, F., Meroni, M., Urbano, F., Royer, A., Atzberger, C., Lemoine, G., ... & Haesen, D. (2015). Remote sensing time series analysis for crop monitoring with the SPIRITS software: new functionalities and use examples. Frontiers in Environmental Science, 3, 46.

Sharma, M. P., Manoj, Y., Prawasi, R., Pavan, K., & Hooda, R. S. (2011). Cropping system analysis using remote sensing and GIS: a block level study of Kurukshetra district. *Journal of Agricultural and Biological Science*, *6*(10), 45-51.

Stalnaker, J. E., Diddams, S. A., Fortier, T. M., Kim, K., Hollberg, L., Bergquist, J. C., ... & Shirley, J. (2007). Optical-to-microwave frequency comparison with fractional uncertainty of 10-15. *Applied Physics B*, *89*(2), 167-176.

Tavus, B., Kocaman, S., & Gokceoglu, C. (2021). Assessment of flooded areas caused by a dam break (Sardoba dam, Uzbekistan). *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *43*, 291-297.

Turkar, V., Deo, R., Rao, Y. S., Mohan, S., & Das, A. (2012). Classification accuracy of multi-frequency and multi-polarization SAR images for various land covers. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *5*(3), 936-941.

Vibhute, A. D., & Gawali, B. W. (2013). Analysis and modeling of agricultural land use using remote sensing and geographic information system: a review. *International Journal of Engineering Research and Applications*, *3*(3), 081-091.

Vollrath, A., Lindquist, E., Jonckheere, I., & Pekkarinen, A. (2016, August). Open foris SAR toolkit-free and open-source command line utilities for automatized sar data pre-processing. In *Living Planet Symposium* (Vol. 740, p. 31).

## Web references

https://haryana.gov.in/about-haryana/
https://agricoop.nic.in/en/agriculturecontingency/haryana
https://earthdata.nasa.gov/learn/backgrounders/what-is-sar
https://www.fao.org/3/i7959e/i7959e.pdf

## Citation

Singh, D., Pandey, N., Atri, P., Kumar, P., Singh, S. (2024). Kharif Crop-Type Mapping of Haryana State using Geospatial Approach In: Dandabathula, G., Bera, A.K., Rao, S.S., Srivastav, S.K. (Eds.), Proceedings of the 43rd INCA International Conference, Jodhpur, 06–08 November 2023, pp. 283–293, ISBN 978-93-341-2277-0.