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Acreage estimation of wheat and onion for districts of north Maharashtra using remote sensing and GIS

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Abstract
Crop acreage data and crop distribution in different districts are essential for the planning and implementation of various governmental policies. The current study was conducted for three districts of North Maharashtra growing wheat and onion crop using multi-spectral, multi-date Sentinel 2A satellite data for *Rabi* season of 2020-21. The Ground Truth of 54 sites was taken during the study. Time series NDVI stack of multi-date Sentinel 2A data was prepared in ERDAS Imagine software. The ERDAS Imagine version 20 and ArcGIS version 10.2 software were used for all remote sensing and GIS analysis. Hybrid classification method using K-means clustering and visual analysis was used for identification and acreage estimation. Unsupervised classification was carried out on resultant multilayer dataset and a classified image with 100 classes of clusters was generated. Reference Temporal Spectral Profile (RTSP) based on ground truth data was used for supervised classification. Acreage of wheat and onion estimated using remote sensing was then compared with statistics given by Department of Agriculture, Government of Maharashtra. Wheat and onion acreage for the study area using this approach is found 172903 ha and 190404 ha which is deviating 3.66 and 9.08 percent from than statistics given by the Department of Agriculture.

Keywords: NDVI, RTSP, ERDAS imagine, sentinel 2a, crop acreage

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop after rice in India. It is enriched with many nutrients like carbohydrates, vitamins and proteins. In India, wheat is cultivated in a variety of soil types. Wheat grows well in well-drained loams and clay loams. Wheat cultivation needs a cool climate and moderate rainfall. Wheat can grow effectively in temperature ranges between 16 °C to 25 °C.

Onion (*Allium cepa* L.), also known as bulb onion is a vegetable that is widely cultivated. India is the second largest producer of onion in the world next to China. Maharashtra is leading state in the production of onion in India followed by Madhya Pradesh, Karnataka and Gujarat. Onion can be cultivated in a variety of soil types, including sandy loam, clay loam, silt loam, and heavy soils. The ideal temperatures for the vegetative phase and bulb development are 13 °C to 24 °C and 16 °C to 25 °C, respectively.

Traditionally, crop acreage estimates are derived on thorough enumeration by revenue agencies (Giradwari system), sample surveys, and personal assessments by local Patwaris. In this approach, the patwari must dedicate sufficient time and attention to the Girdawari. Because the Patwari agency is overwhelmed with several tasks and must deal with a broad geographical jurisdiction, it takes longer and produces incorrect findings. Planners and policymakers must have accurate and timely crop area estimates in order to make crucial choices on procurement, storage, public distribution, export, import, and other related concerns for successful and timely agricultural development.

Remote sensing has opened up innovation in agricultural statistics across the world. Through officially supported programmes, remotely sensed spectrum satellite data has been regularly used for this purpose. Area estimates for important crops such as rice, wheat, sugarcane, onion, sorghum, peanuts, and cotton are said to be prepared on a regular basis. The enhanced resolution and multitemporal spectral images of modern remote sensing satellites may be used to improve accuracy even more. This technique may be used in small areas such as panchayats and even at the village level. Remote sensing-based acreage estimate is both time efficient and accurate. Furthermore, remote sensing simplifies an otherwise arduous operation.

Materials and Methods

A) Study area

The study area includes three districts of North Maharashtra i.e. Dhule, Jalgaon and Nashik which are growing *Rabi* wheat and onion prominently. The study has been carried out for the *Rabi* season of 2020-21. The study area is situated between 73° 78' 98" to 75° 52' 77" E longitude and 19° 99' 75" to 21° 03' 96" N latitude covering an area of 34542 km^2. The average annual rainfall of the study area is between 600-1000 mm.

B) Remote Sensing Data used

The images from Multispectral Instrument sensor (MIS) of Sentinel 2A satellite of five months of *Rabi* season i.e. December to April of the year 2020-21 for wheat and onion crop were obtained. Details of images acquired with date of pass are given in Table 1. The research area was covered by 10 subset images, which were acquired and analysed using ERDAS to generate NDVI (Normalized Difference Vegetation Index) images for each date a satellite passed over.

Table 1: Sentinel 2A data used for the study

Sr. No.	Satellite	Sensor	Date of pass
1.	Sentinel	MSI	15-12-2020
2.	Sentinel	MSI	25-12-2020
3.	Sentinel	MSI	19-01-2021
4.	Sentinel	MSI	29-01-2021
5.	Sentinel	MSI	13-02-2021
6.	Sentinel	MSI	28-02-2021
7.	Sentinel	MSI	15-03-2021
8.	Sentinel	MSI	25-03-2021
9.	Sentinel	MSI	09-04-2021
10.	Sentinel	MSI	19-04-2021

C) Supplementary Data

The MRSAC, Nagpur provided water bodies, urban sprawl, forests, wastelands, and other non-crop components that were used to build the non-crop mask (NCM) of the research area. The district-wise crop data released by the Department of Agriculture, Government of Maharashtra, on the website www.krishi maharashtra.gov.in (Crop statistics, 2020-21) related to study area was used as a guide for interpreting the outcomes of acreage estimation.

D) Ground Truth Data

The ground truth (field visit) for the *Rabi* season of 2020–21 was conducted in the research region between 24^{th} to 30^{th} January 2021. The data on wheat and onion from 54 places was gathered. Hand-held GPS, Mobile with Android operating system with a good quality camera and Ground Truth Proforma Sheets was used for the survey of study area. The study area and ground truth locations are given in Fig 1.

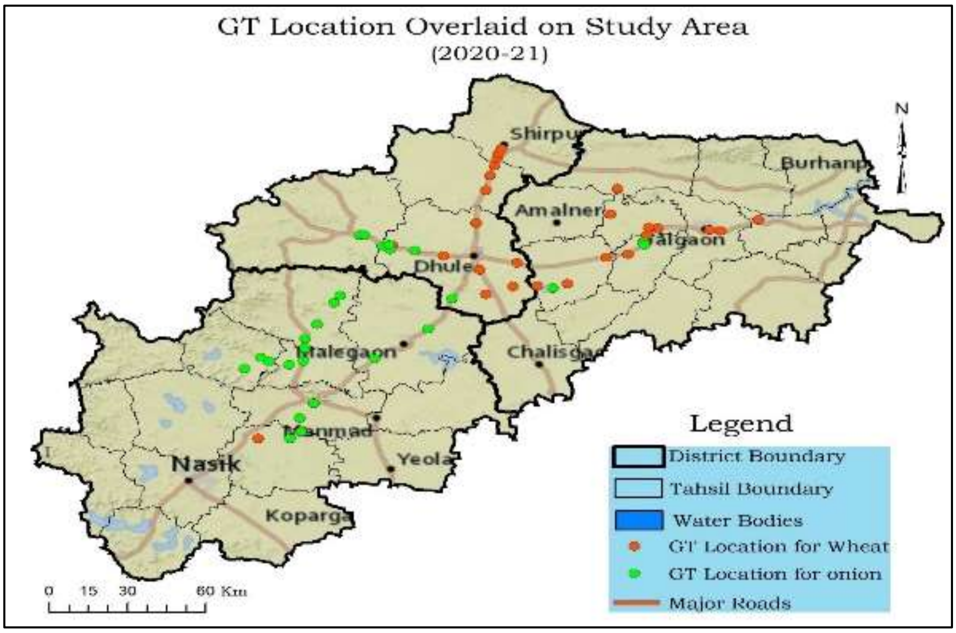

Fig 1: Study area and ground truth locations

E) Processing of Image

The flow chart of the processing of the image is depicted in Fig. 2 and the detailed procedure is given as under,

1. **Preparation of Reference Temporal Spectral Profiles (RTSP):** The spatial coordinates of GT locations were put onto the images. In line with the information acquired during field visits, crop-polygons (training sites) were tagged on the image with an acquisition date close to the date of the field observation. For each satellite image acquisition date an NDVI image was created along with a layer stack. The general signature of the crop is generated by plotting the NDVI values on the various acquisition dates against the optimal crop period. These signatures offer the reference temporal spectral profile (RTSP) of

Rabi wheat and onion which assists in crop identification.

2. **Data load reduction of multi-date RS dataset:** The non-crop mask (NCM) was generated by overlaying the NDVI stack with the dataset that already had information about built-up areas, slopes, forests, wastelands, and so on. To reduce the number of data pixels that were required to be subjected to K- means clustering, all pixels that belonged to non-agricultural regions were masked out.
3. **K-means clustering:** Unsupervised classification was performed using an NDVI stack dataset that had not been cropped. A total of 100 classes were chosen with a convergence threshold of 0.999 and 30 iterations. The ultimate result of K-means clustering was a classified raster image with 100 classes. In addition, a signature file containing the signatures of all 100 classes was received. The signature file generates the Temporal Spectral Profiles (TSPs) for each class. The available RTSP of the wheat and onion crop as well as the substantial local knowledge of analyst were then utilised to visually compare each of the 100 TSPs classes.
4. **Supervised classification:** On the cluster file and multi-date subsets the GT point layer was superimposed. Using accessible RTSPs, visual interpretation was conducted for unclassified pixels and/or pixels that could not be confidently assigned to any crop class. Crop-polygons were assessed and labelled using visual analysis.

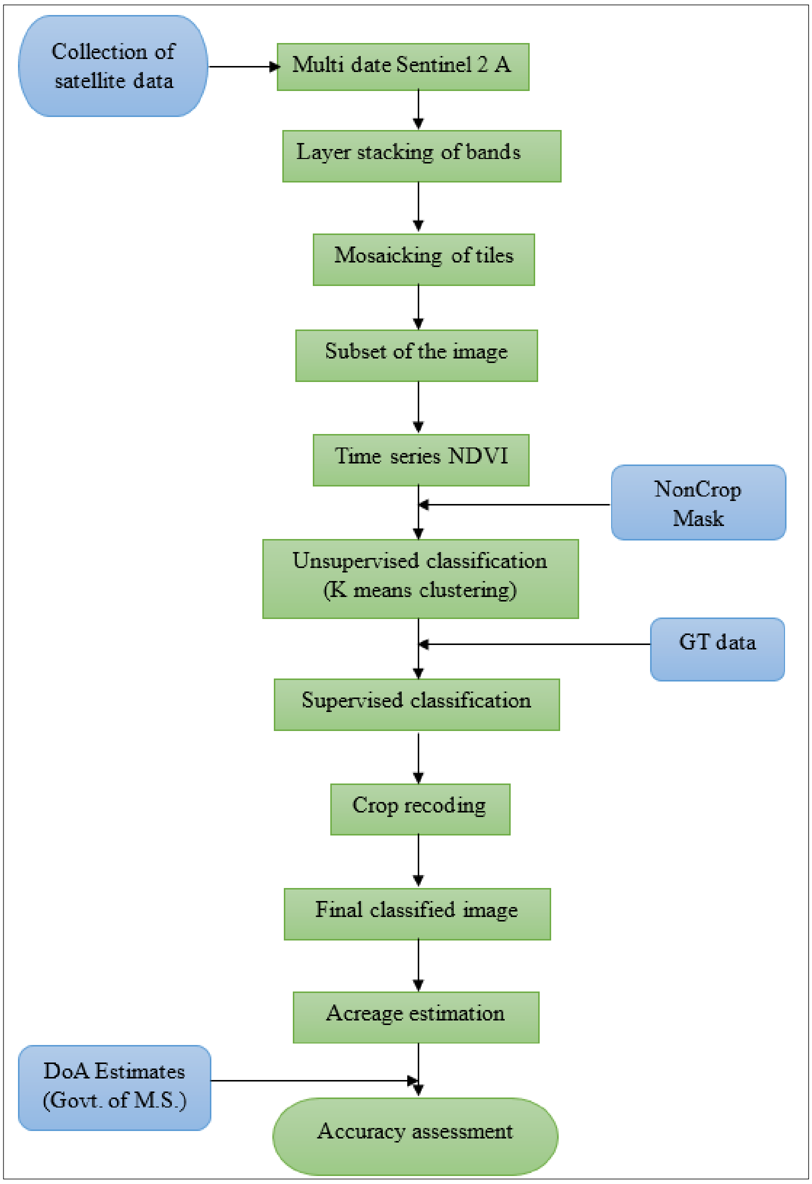

Fig 2: Flowchart for acreage estimation

Results and Discussion

It was found TSPs of 22 and 19 classes matched with RTSPs of wheat and onion. Fig. 3 shows the results of unsupervised classification and after that, this image was used for supervised classification using visual analysis and a signature editing tool. The outcome of supervised classification was subjected to crop recording, which combined related clusters to produce a real thematic map. The spatial distribution of wheat and onion and other crops is represented by choosing different colours for different classes. The final classified image is shown in Fig. 4 The district wise pixel count of wheat and onion was obtained by applying zonal attributes/majority count function of ArcGIS. For this process, option of intersection/union and ignore zero values were selected. After running of process, the attribute of the vector layer show majority count i.e. number of pixels of wheat and onion in each district. The area under wheat and onion crop in each district was obtained by multiplying these number of pixels by resolution of the data i.e. 10x10 m and converted into hectares.

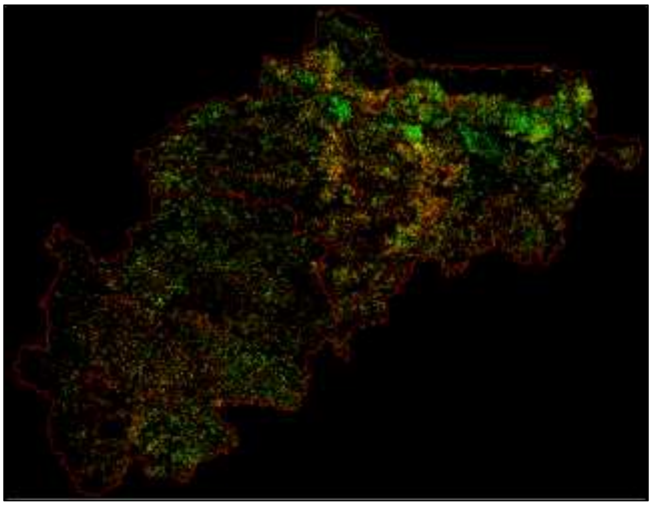

Fig 3: Classified image obtained after unsupervised classification

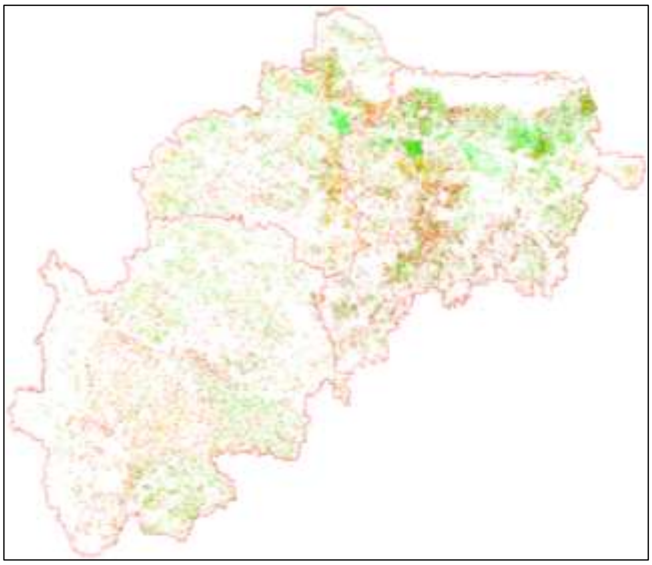

Fig 4: Final Classified image

The results of acreage estimation of wheat and onion were then compared with reference data received from crop statistics by the Department of Agriculture, Government of Maharashtra. Relative Deviation in terms of Percent Deviation was calculated district wise and also for study areas are given in Table 2.

Table 2: Estimated district-wise acreage of wheat and onion

Crop	District	RS estimates (ha)	DOA estimates (ha)	Deviation (%)
Wheat	Dhule	44386	41609	6.67
	Jalgaon	67927	61747	10.01
	Nashik	60590	63442	-4.50
	Total	172903	166798	3.66
Onion	Dhule	16529	14789	11.77
	Jalgaon	10359	9891	4.73
	Nashik	163516	149866	9.11
	Total	190404	174546	9.08

Remote sensing-based wheat and onion crop acreage when compared with average data collected from the Department of Agriculture showed an average deviation of 3.66 and 9.08 percent on study area basis. For Dhule, Jalgaon and Nashik district percent deviation of 6.67, 10.01 and -4.50 percent was found for wheat crop whereas 11.77, 4.73, 9.11 percent was found for onion crop respectively.
Similar results related to the accuracy of acreage estimation were found by Pimpale *et al.* (2015) [6] for wheat, Ahmed R., and Sajjad H. (2015) [2] for Boro Paddy, Aich *et al.* (2017) [2] and Rawat *et al.* (2021) [7] for wheat acreage.

Conclusion

A hybrid technique based on K-means clustering and visual analysis was used for identifying wheat and onion crops and estimating their acreages revealing that the resulting acreages were quite similar to the real statistics provided by the Department of Agriculture, Government of Maharashtra. Various linear characteristics including highways, canals, water bodies etc. were accurately identified in the current investigation as non-wheat and non-onion classes. Conceptually, this methodology is sounder than single-date spectral indexes which only use spectral data throughout a limited crucial period maximum vegetative development phase. This is because multi-date Remote sensing data are supplied for rigorous and recurrent analysis.

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