Vegetation indices based farm-level mustard crop classification for the analysis of cropping pattern in Rabi 2021 and change in crop trend 2019 to 2021 of Kota District, Rajasthan

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Abstract: ***Remote sensing technology is used to quickly investigate as an innovative, standardized, potentially cost-effective, and faster method for crop acreage estimation. Furthermore, when compared to previous monitoring systems, Sentinel-2 satellite data has tremendous advantages since it delivers five-day interval, topographical, and up-to-date crop info at multiple phases. The main Rabi oil seed crop in Rajasthan is rapeseed and mustard. This study explores the use of the time series NDVI based farm level acreage estimation depending on the condition of the chlorophyll content. It also studies the changes in the cropping patterns and trends in Kota district, Rajasthan using the Google Earth Engine cloud platform along with the NCMS Mobile application for ground truth. Results indicate the reliability of the developed method for estimating acreage down to the farm level. Estimated Results for found to be in close agreement with authenticated government data. Two of the studied sub-districts showed significant cropping patterns. Classification accuracy for mustard ranged between 78-90 percent, while the overall classification accuracy 80-90 percent. The study concludes with the use of technology-based acreage estimations for faster and more reliable results.***

Keywords**: NDVI based Acreage Estimation, Cropping Pattern, GEE, Cadastral level Crop Classification**

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I. INTRODUCTION

India is the world's fourth largest supplier of oilseeds, with around 20% of worldwide area and 10% of worldwide productivity. One of the India's the major oilseed crop in Rabi season is Rapeseed-mustard (Brassica spp.) [1]. In India five major mustard producing states are Rajasthan (48%), Haryana (12%), Madhya Pradesh (10%), Uttar Pradesh (9%) and West Bengal (7%) accounting for more than 85% Rapeseed-mustard production [16]. According to the Ministry of Agriculture and Farmers Welfare's Area and Production Statistics (APY) figures, these states account for approximately 84% of total Rapeseed and Mustard acreage and 90% productivity [15]. Typically, mustard crop seeding in Rajasthan takes place between middle of September to end of October. Consequently, the harvesting season lasts until March. With low humidity and almost no precipitation during blooming, a temperature of 18°C-25°C is suitable for the development of the mustard crop. For optimum production, it requires a much greater temperature during initial phases of growth, cool weather, and a clear sky throughout the vegetative period. Other variables affecting mustard crop yield include moisture stress (drought), heat stress, soil salinity, frost, and so on.

However, ideal conditions do not exist during all the seasons resulting in below-par crop performance leading to a loss of income for farmers. Therefore, it is very crucial to estimate the crop acreage and productivity for providing proper aid to farmers and government agencies in planning and development. Traditionally, it was done using tedious manual methods such as crop cutting experiments with the help of remote sensing techniques, satellite imagery can be used to provide crop acreage and production estimation at various levels [2], [3], and [8]. Remote sensing, at different spatial resolutions, has also been used for estimation of different crop characteristics Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), biomass, fraction of Absorbed Photosynthetically Active Radiation (fAPAR) etc. that are directly related to crop production.

NDVI is a basic indicator of plant health. Building time series of NDVI allows to monitor the agricultural crops based on the state of the leaf canopy from time to time. Moreover, it is very important to detect an abnormal drop/ pattern change of NDVI at the beginning of the season [7]. Which can be achieve through a comparison of the present field performance with the same data but for previous years. A drawdown in indicative parameters suggests possibility of a potential problem that identified and addressed to minimise the risk. These may be pests, plant diseases, abiotic stress etc. In addition, timely detection will enable the stakeholders to take appropriate steps for preventing crop loss and to study the cropping pattern change for stakeholders like commodity vendors.

It is observed that crops have different thresholds NDVI value throughout their phenological stages [4] and increases with duration throughout the vegetative phase and subsequently it declines. The phenological stages of selected crops are shown in Tables I, II and III for various crops grown in the study area. Time-series NDVI data to track winter wheat crop expansion and plant developmental stages in 2016. Researchers observed that plant growth stages such as vegetative, heading, and harvesting could be distinguished by NDVI curvature exhibiting local peak value in this research [9].

TABLE I. MUSTARD CROP CALENDAR FOR RAJASTHAN STATE

Rapeseed & Mustard	Sep SF	Oct FF	Oct SF	Nov FF	Nov SF	Dec FF	Dec SF	Jan FF	Jan SF	Feb FF	Feb SF	Mar FF	Mar SF
Sowing window													
Vegetation phase													
Flowering phase													
Grain filling													
Maturity phase													
Harvest window													

TABLE II. GRAM CROP CALENDAR FOR RAJASTHAN STATE

Gram	Sep FF	Sep SF	Oct FF	Oct SF	Nov FF	Nov SF	Dec FF	Dec SF	Jan FF	Jan SF	Feb FF	Feb SF	Mar FF	Mar SF
Sowing window														
Vegetation phase														
Flowering phase														
Grain filling														
Maturity phase														
Harvest window														

TABLE III. WHEAT CROP CALENDAR FOR RAJASTHAN STATE

Wheat	Sep FF	Sep SF	Oct FF	Oct SF	Nov FF	Nov SF	Dec FF	Dec SF	Jan FF	Jan SF	Feb FF	Feb SF	Mar FF	Mar SF
Sowing window														
Vegetation phase														
Flowering phase														
Grain filling														
Maturity phase														
Harvest window														

Therefore, keeping the above facts in view as different crop has different phenological cycle and the time-series profiles for mustard crop can be clearly distinguished from Gram and Wheat the other major crops grown in the district.

The main objectives of this study

- NDVI based farm-level crop classification on Sentinel-2 satellite images from Google Earth Engine (GEE) Cloud.
- Analysis of mustard crop sowing pattern in Kota district for Rabi-2021-22.
- Analysis of mustard crop trend over past three years in Kota district, Rajasthan.

II. STUDY AREA

Rajasthan is the largest State in India. Kota district (Figure 1) located in the southeastern part of Rajasthan. It lies between 24°25' and 25°51' North latitude and 75o37' and 77o26' East longitude. "The Chambal is the principal perennial river of the district". The 62.15 % irrigated area of district. The district has six Tehsils namely Ladpura, Digod, Pipalda, Ramganj mandi, Sangod and Kanwas. Out of these districts Ladpura, Digod and Pipalda Tehsils fall under Chambal command area whereas remaining tehsils Ramganj mandi, Sangod and Kanwas comes under non-command area. The main cultivated crop areas are wheat (46%), mustard (24%), coriander (21%), garlic (6%) and others (3%) during Rabi season and soybean (77%), black gram (9%), Paddy (8%) and others (6%) during Kharif season. The total cultivated area of the district is 3.4 lakh ha out of which 2.1 lakh ha is irrigated [17].

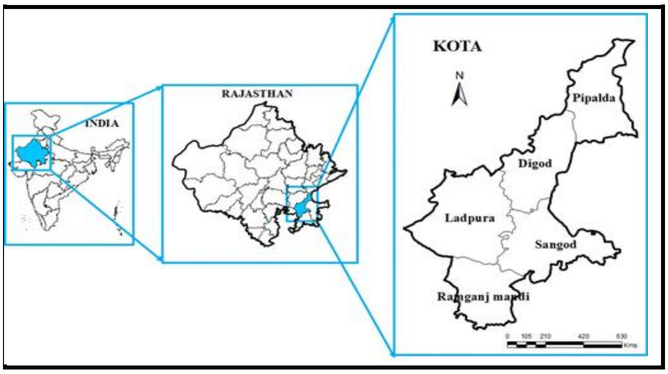

Fig. 1. Location map of Kota district Rajasthan state

III. DATA USED

A. Satellite Data

The Copernicus – The European Earth Observation program Sentinel-2 mission consists of a pair of two polar-orbiting satellites oriented at 180 degrees to each other in the similar sun-synchronous orbital. Its huge swath coverage (290 km) and long repeat interval (10 days at the equator with 1 satellite, and 5 days with 2 satellites in cloud-free weather, resulting in 2-3 days at mid-latitudes) will closely observe Earth's surface changes [14]. Sentinel-2 has a spatial resolution of 10 to 60 meters in the visible, near infrared (NIR), and short-wave infrared (SWIR) spectral zones, with 13 spectral bands, ensuring that variations in plant status, includes temporal variation, are captured, and also minimizes impact on the quality of images[11]. All optical datasets processed with a multi-temporal algorithm to detect clouds and their shadows on the soil and correct for atmospheric disturbances by applying the method developed [12], which is based on the assumption that surface reflectance's and aerosol optical properties vary differently according to time and location. Such data obtained is use to derive vegetation index NDVI, which is computed by using spectral bands in red and near-infra- red [13]

B. Field Survey data

To distinguish land use/land coverings and crop categories in satellite data, field survey data/ground truth (GT) data is necessary. The evidence gained about the ground characteristics to correlate with data from satellite known as the test dataset. Two major reasons to perform GT's: to collect important crops related information and detailed data as an input in the study of satellite data; To acquire essential data apart from accurate information as a guide in the interpretation of satellite data. Total GT points collected using random sampling technique in 2019, 2020, and 2021 are 90, 210, and 89, respectively. The GT data collected by the National commodities Management Services Limited (NCML) field staff using an in-house developed smartphone-based android Application, which is NCML Crop monitoring survey (NCMS) as shown in Figure 2. The

GTs separated into train and test samples on a 60-40 % basis for crop classification.

Fig. 2. NCMS android Mobile application Interface for GT points collection

C. Cadastral data

Land records maps kept inside village bounds with suitable village indexes specifying relationship, location, and alignment among plots representing the village in the current area of activity. "Bhunaksha" is a cadastral mapping program created by the National Informatics Centre (NIC) to help manage digitised cadastral maps utilising open-source applications and libraries [5], [6], and [10].

IV. METHODOLOGY

A. Mustard Crop Classification

Supervised classification algorithms are dependent on external knowledge about the research region, which derived from GT data. The acreage estimating technique for rapeseed and mustard involves a two-step method that considers determining the best date to acquire from sentinel-2 satellite data (last week of October to first week of January) and obtaining temporal NDVI images using Google Earth Engine (GEE) cloud platform. Signatures of Mustard crop as well as other land cover features were distinguished using GT data, tone, texture, pattern, and correlation from satellite images, and supervised classification used in ERDAS Imagine software to distinguish Mustard crop using AOIs (areas of interests) of various crops and other land cover features. After the classification, Using GT data, a mustard crop mask created and classification accuracy assessment.

B. Sowing Trend for Rabi 2021-22

Rapeseed & Mustard Sowing trend comprises of optimum date selection from mustard sowing window in Rajasthan State (Oct 1st to 31st) for acquiring satellite data and to generate temporal NDVI images on GEE cloud platform at 10 days interval. Which are, image-1 from area October 31st to November 10th 2021 image-2 from November 11th to November 20th 2021 Similarly 3rd Image from November 21st to November 30th 2021 image-1 and 2 mask with classified mustard crop output get the minimum and maximum NDVI values for both the images. Slice the third image using threshold values get from Mustard crop masked NDVI images-1 and 2 in ERDAS Imagine software. Assign the class values and colors for each class early, on time and Late sowing categories. Sowing trend is very crucial for yield estimation.

C. Cadastral Data preparation

Bhunaksha is a Cadastral Mapping Software developed by NIC using Open Source Applications and libraries to facilitate management of Digitized Cadastral Maps. The scanning, digitization, verification of cadastral maps are the pre-processes and input to Bhunaksha application [5], [6], [10]. The interfaces implemented differently for different states based on the structure of that state's ROR database. Go to Rajasthan Bhunaksha Web application; Open Rajasthan select from drop down "District: 26 Kota; Tehsil: 120 Digod; Revenue Circle (RI): 2344 Budadhita; Patwar Halka: 09389 Banetiya; Village: 38290 Banetiya; Sheet No: 001 001" take screen shot. Then georeferenced in any GIS Software is like QGIS / Arc GIS then digitize the cadastral boundary using base maps and add Survey/Khasra numbers for each polygon in attribute table of shapefile as shown in Figure 3.

Fig. 3. Banethiya village Cadastral map in Digod tehsil, Kota district

D. Identification of Cropping Patterns with in a district

After post-classification processes on satellite images of prior years, calculated the sub-district (tehsil) level crop area statistics using GIS software tools like Environmental Science research Institute (ESRI) Arc GIS / Quantum GIS (QGIS) followed by comparing the obtained results. The summary of methodology flowchart depicted in figure 4.

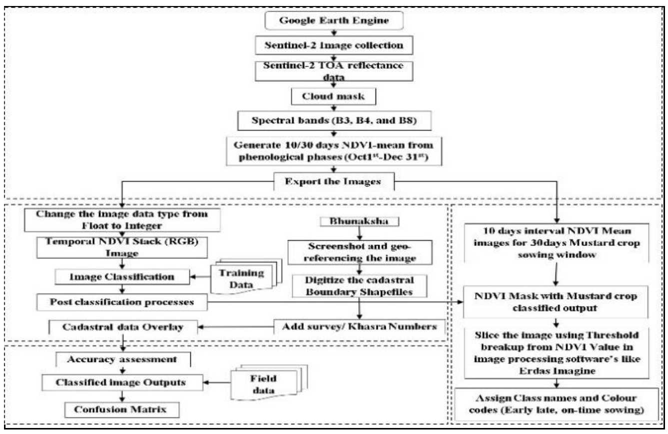

Fig. 4. Methodological approach flow Chart

V. Results and Discussion

NDVI values of Rapeseed & Mustard is higher compared to that of competing crops, such as wheat and gram. This is because during December, Mustard was in flowering stage while wheat and gram was in germination to early vegetative stage, resulting higher NDVI values as shown in (Figure 5) of sentinel-2 satellite (10 m spatial resolution) data showed below.

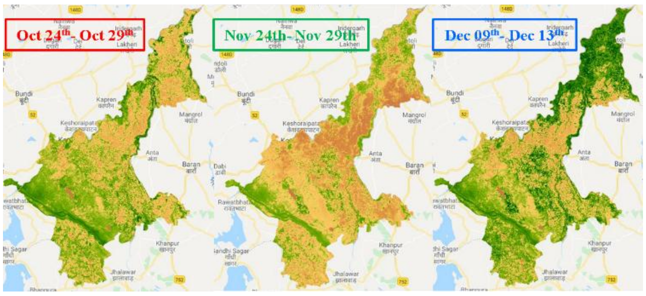

Fig. 5. Temporal NDVI Images for Kota district

By Mid of February science mustard crop start maturing, the NDVI values are expected to show a declining trend. The spectral differences and phenological stages between the crops were used to classifying the crops. A typical Overlaid Rapeseed & Mustard classified image in Figure 6, along with the temporal NDVI Stack of the Sentinel -2 Satellite Image, which was used to classify it.

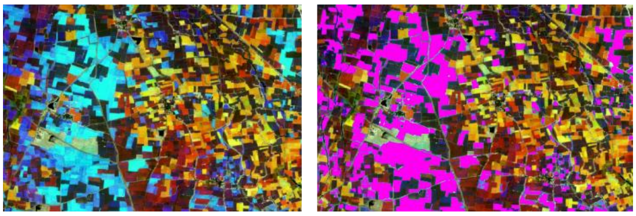

Fig. 6. NDVI Composite Stack Image (left) along with Overlaid Classified image (Right)

After classifying the crops, the sub-district boundaries were overlaid on the classified image to generate sub-district (tehsil) level crop area as shown in Table IV. During 2019 as per Indices based area estimation, it was 20353 Hectares compared to 24894 hectares as per government of Rajasthan Department of Agriculture. While during 2020, the acreages are 49674 Hectares compared to 28110 Hectares and during 2021, the acreages are 65206 Hectares compared to 62390 Hectares, respectively. Areas estimated are in close agreement with data published by the government of Rajasthan validating the use of Remote sensing technology-based acreage estimation.

TABLE IV. Sub-district (Tehsil) wise Rapeseed & Mustard area statistics for 2019, 2020 and 2021

District	Tehsil	2021	2020	2019
		Area in Ha	**Area in Ha**	**Area in Ha**
Kota	Pipalda	31415	10619	5514
	Digod	13282	5657	1877
	Ladpura	5998	7995	3770
	Ramganj Mandi	4751	12427	10862
	Sangod	9759	12976	7329
Total Area in Ha		**65206**	**49674**	**29353**

Mustard crop yield also depends on time of sowing (early, timely and late sown). These indices-based studies give an opportunity to evaluate sowing pattern of Kota district in Rajasthan the results are as shown in Table 5. Eventually the results of estimated yields will help in better planning for stakeholders along the supply chain and government agencies.

TABLE V. Sub-District (Tehsil) Wise Sowing trend Area for Rabi-2021-22 Kota district in Rajasthan

District	Tehsil	Early Sown Area in Ha	Late Sown Area in Ha	Timely Sown Area in Ha
Kota	Pipalda	5742	11930	13740
	Digod	3480	3720	6087
	Ladpura	2148	1526	2324
	Ramganj Mandi	450	2727	1572
	Sangod	1240	4980	3532
Total Area in Ha		**13060**	**24882**	**27256**

The cropping pattern in the northeastern and southwestern tehsils (Pipalda and Ramganj mandi) in Kota district is greater over comparison between 2019 and 2020, with fewer alterations observed between 2020 and 2021.

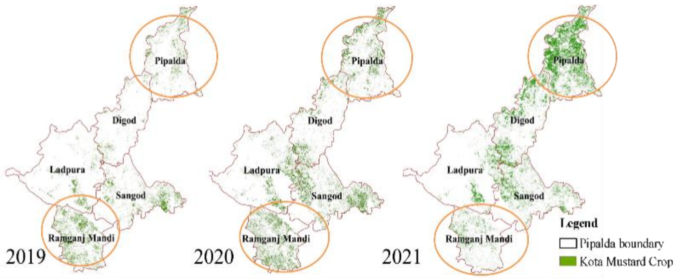

Fig. 7. Pre-Harvest Mustard Crop Classified images for 2019, 2020 and 2021

However, when compared 2019, during 2021(Figure 7) , it is observed that significant differences in crop acreages were observed for Pipalda, Ramganj mandi as shown in Figure 8.

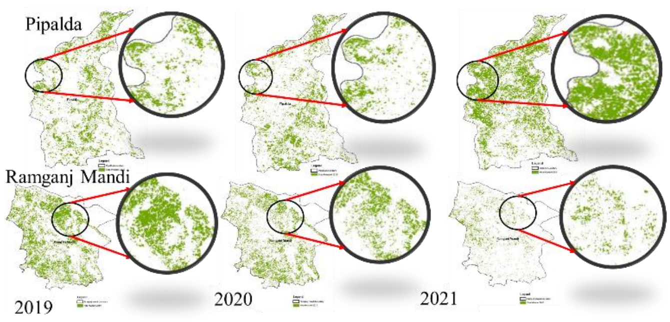

Fig. 8. Mustard Crop pattern change from 2019 to 2021 for Pipalda and Ramganj mandi tehsils in Kota district

This study concludes Cadastral maps allow for detailed mapping of yearly or regular fluctuations in the study area, making estimates of the area and production of every farm levels. They also enable for the clear and precise monitoring of the impact of changes in cropping patterns. Crop classification at the farm level is achievable using temporal

NDVI images and monitoring. Classified image overlay with Banethiya village cadastral map (Figure No.9) reveals multiple mustard crop fields that significantly distinguish in classified over the sentinel-2 A/B two constellation satellites at 180^0 phase with 10m spatial resolution given by the European Space Mission (ESA) Copernicus (ESA) programme.

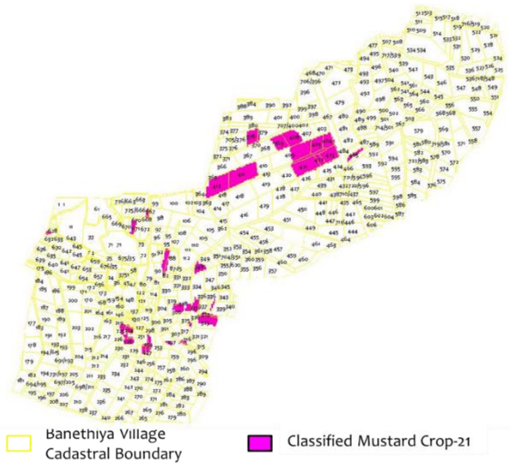

Fig. 9. Banethiya village in Digod tehsil Cadastral map overlay with classified image

VI. Accuracy Assessment

The quality of a map created using remotely sensed data is validated by comparing it to obtained field data. Accuracy measurement and verification are crucial in remote sensing-based activities because making decisions or conducting research studies with data that is unclear or has low accuracy results in information with low trustworthiness, error propagation effects of minimal usefulness.

The user's accuracy reveals misclassification, which occur when pixels are wrongly labelled as belonging to a recognised class when they should have been classed as belonging to some unrelated. The accuracy of the producer is a false negative, which occurs when pixels of a recognised class are categorised as anything other than that category.

Here on 2019-20 classified picture, 46 of 50 reference pixels for mustard crop were perfectly identified as mustard crop, while 4 were incorrectly classified as other crops shown in Table VI.

TABLE VI. Error Matrix for Crop Classification Accuracy to 2019-20 Rabi

	GT Points Rabi 2019-20				**User Accuracy**
Classified Rabi Image 2019-20		**Mustard**	**Other Crops**	**Totals**	
	Mustard	46	13	59	**78%**
	Other Crops	4	27	31	**87%**
	Totals	50	40	90	
	Producer Accuracy	92%	68%		**81%**
Overall Accuracy					**81%**

On the 2020-21 classification image, 52 of the 62 reference pixels for mustard crop were correctly identified as mustard crop, while 6 were accurately classified as other crops shown in Table VII.

TABLE VII. Error Matrix for Crop Classification Accuracy to 2020-21 Rabi

	GT Points Rabi 2020-21				**User Accuracy**
Classified Rabi Image 2020-21		**Mustard**	**Other Crops**	**Totals**	
	Mustard	52	6	58	**90%**
	Other Crops	10	142	152	**93%**
	Totals	62	148	210	
	Producer Accuracy	**84%**	**96%**		**92%**
Overall Accuracy					**92%**

On the 2021-22 classification image, 73 of the 73 reference pixels for mustard crop were correctly identified as mustard crop, while no pixels accurately classified as other crops. Because no other crops identified on ground at the time of field-survey conducted shown in Table VIII.

TABLE VIII. Error Matrix for Crop Classification Accuracy to 2021-22 Rabi

	GT Points Rabi 2021-22				**User Accuracy**
Classified Rabi Image 2021-22		Mustard	Other Crops	**Totals**	
	Mustard	73	15	88	**83%**
	Other Crops	0	1	1	**100%**
	Totals	73	16	89	
	Producer Accuracy	100%	6%		**83%**
Overall Accuracy					**83%**

VII. Conclusion

In all three years, vegetation indices-based classification utilising GEE Sentinel-2 satellite data was effective for farm level classification, with an overall accuracy of mustard crop over 81% with supervised classification. Cropping patterns shifted from 2019 to 2021 (tehsils) mostly in Ramganj-Mandi and Pipalda sub-districts, substantial variations noted in the mustard crop. Furthermore, the results show that the mustard-sowing tendency in the Kota district is early, timely and late sowing mustard acreages, which has an influence on output.

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