Wheat Crop Acreage Estimation Based on Remote Sensing and GIS in Jabalpur (Madhya Pradesh, India)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Mapping and classification crop by using satellite images is a challenging task that can minimize the complexities of field visits. The recently launched Sentinel-2 satellite has thirteen spectral bands, short revisit time and determination at three different resolutions (10 m, 20 m and 60 m), besides that, the free availability of the images makes it a good choice for vegetation mapping. This study aims to classify crop, using single date Sentinel-2 imagery within the Jabalpur, state of Madhya Pradesh, India. The classification was performed by using Unsupervised Classification. In this study, four spectral bands, i.e., Near Infrared, Red, Green, and Blue of Sentinel-2 were stacked for the classification. The results show that the area of wheat crop corresponds to 83.07%; Gram/ Pulses, 14.64%; and other crop, 2.28%. The overall accuracy and overall Kappa Statistics of the classification using Sentinel-2 imagery are 85.71% and 0.819%, respectively. Therefore, this study has found that Sentinel-2 presented great potential in the mapping of the agriculture areas of Jabalpur by remote sensing.

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1. INTRODUCTION

The two major Components of crop production forecasting using remote sensing and GIS data are crop acreage estimation and yield forecasting [1,2]. Agriculture is the backbone of Indian economy, contributing with about 40 percent of the Gross National Product and providing livelihood to around 70 percent of the population. Wheat is the second most important food crop, just after rice, and contributes to the total food grain production of the country to the extent of about 25 percent [3-5].

India, at present time, faces a high complexity agricultural system, due to small-sized fields, large number of crops, field-to-field variability in crop phenology and management practices (Sahai 1985). Estimating crop production is of great utility in framing and implementing agricultural management. In different parts of the world, many types of research have demonstrated the use of remote sensing data for agriculture mapping [6,7]. Some of these applications include crop acreage and production estimation, cropping system analysis, agricultural water management, drought assessment and monitoring, precision farming, soil resources mapping, climate impact on agriculture and so on [8,9] (Navalgund and Ray, 2000). This paper aims to estimate the level of wheat production in Jabalpu area using remote sensing and GIS technologies.

Campbell et al. [10] has evaluated direct use of temporal spectral data for wheat acreage estimation in Australia. In India, Dadhwal & Parihar (1985) haveused remotely sensed data for wheat production estimation in Karnal district of Haryana State.

1.1 Study Area

Jabalpur comes under Kyamore Plateau and Satupra hills agro-climatic zone. The district boundary is located between the latitudes 22.49 N and 24.08 N & and the longitudes 75.25 E and 80.53 E. The area of the district is 5,655.51 km^2, according to the 2011 census; it is the third-largest urban agglomeration in Madhya Pradesh and the country's 38th-largest urban agglomeration. Jabalpur District is located between the watersheds of Narmada and the Son, but mostly within the valley of the Narmada, which here runs through the famous gorge known as the marble rocks, and falls 30 ft. over a rocky ledge. The Jabalpur district has an average altitude of 411 metres, the average temperature of 45C and average annual precipitation of nearly 1.386 mm. It consists of a long narrow plain running north-east and south-west and shut in on all sides by highlands. This plain, which forms an offshoot from the great valley of the Narmada, is covered in its western and southern portions by a rich alluvial deposit of black cotton-soil [11,12]. The north and east belong to basin of the Son River, a tributary of the Ganges and Yamuna, the south and west to the Narmada basin.

1.2 Present Work has been Carried Out Using the Following Datasets

A)-Crop classification data

It includes crop growing period and their duration, probable dates of sowing, cropping pattern, field size, different land cover classes etc. Crop calendars for growing seasons of various crops in the study area are used.

B)-Satellite data

Sentinel-2 image acquired on February 2019 in the growing season has been used. Four bands (NIR, Red, Green, Blue) of Sentinel-2 at 10 m resolution have been utilized for the classification. Sentinel-2 has 13 spectral bands, details of these bands such as names, spatial resolution, along with their corresponding wavelength is shown in Table 1.

2. METHODOLOGY

The proposed methodology for crop classification is shown in Fig. 3. Multi DATA Sentinel-2 imagery has been taken and individual bands of 10 m spatial resolution from NIR, Red, Green and Blue bands were stacked together to create a multispectral image cube. Once the stacked image is generated, a single pixel contains a 4-dimensional vector containing spectral values corresponding the considered bands. Reference dataset has been created by fields survey where ground truth values has been taken using Mobile GPS, apart from this some of the sample are also taken with the help of high-resolution Google earth images .
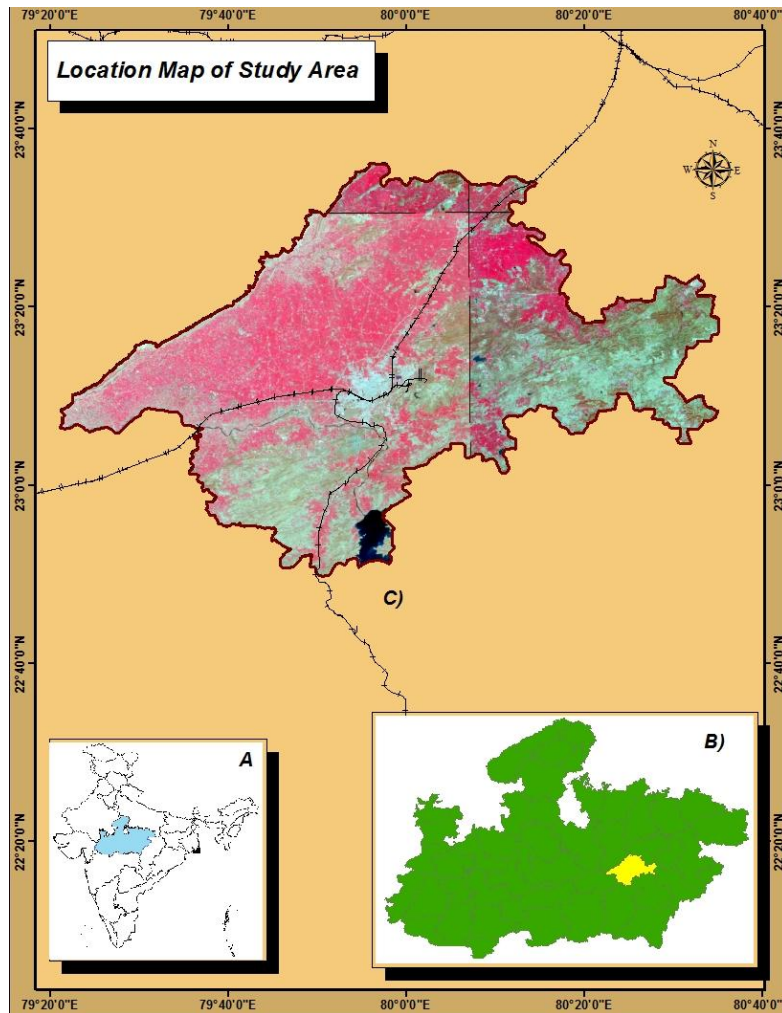
Fig. 1. Location map of the study area. A) Indian states boundaries, with Madhya Pradesh highlighted in blue B) Madhya Pradesh state (green), with Jabalpur district highlighted in yellow C) Jabalpur district

Table 1. Sentinel-2 data used for wheat crop acreage estimation

z	Band name	Spatial resolution (m)	Central wavelength (nm)
Band 1	Coastal aerosol	60	442.7
Band 2	Blue	10	492.4
Band 3	Green	10	559.8
Band 4	Red	10	664.6
Band 5	Vegetation red edge	20	704.1
Band 6	Vegetation red edge	20	740.5
Band 7	Vegetation red edge	20	782.8
Band 8	NIR	10	832.8
Band 9	Narrow NIR	20	864.7
Band 10	Water vapour	60	945.1
Band 11	SWIR – Cirrus	60	1373.5
Band 12	SWIR	20	1613.7
Band 13	SWIR	20	2202.4

Source: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-sentinel-2?qt-science_center_objects=0#qt-science_center_objects
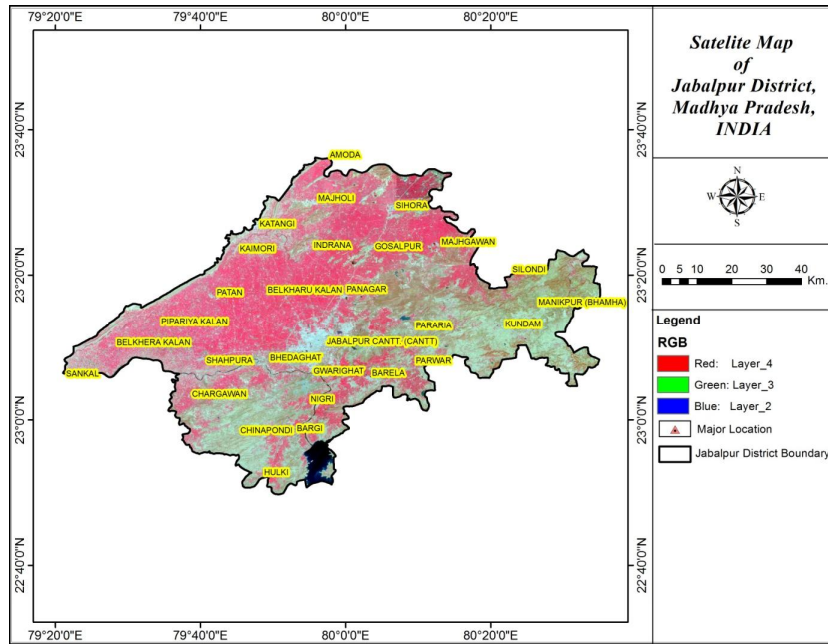
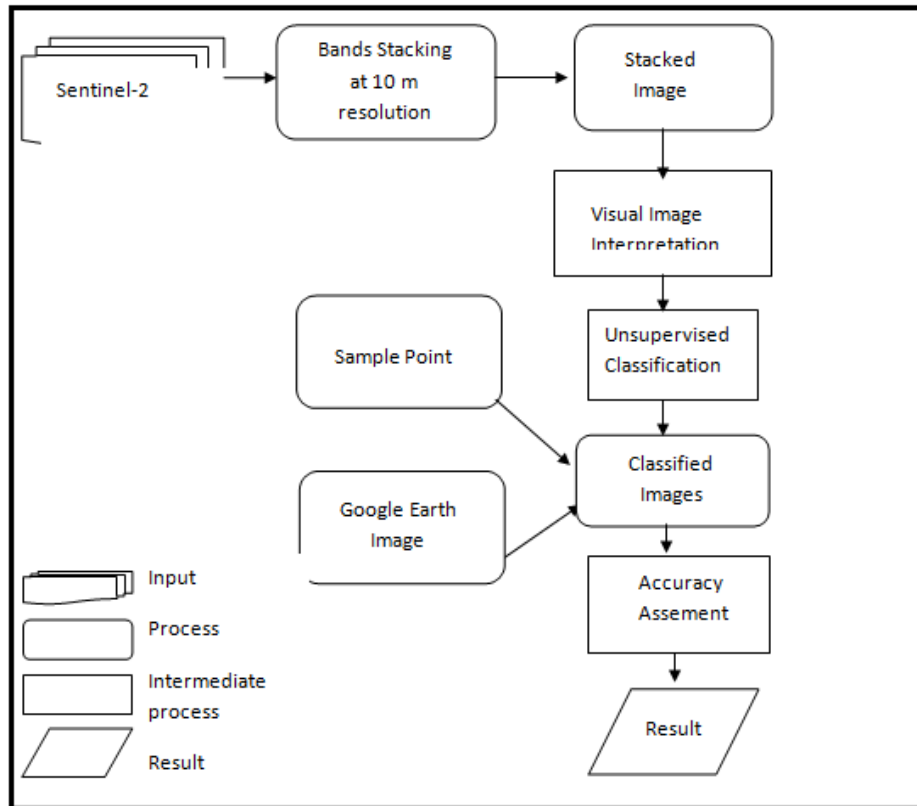**Fig. 2. Satellite image of the study area**

Fig. 3. Flow chart of the methodology (please, mention this figure in the text

Table 2. Comparison between remote sensing data and ministry of agriculture and farmer welfare data for acreage estimates for period 2019-2020

District Jabalpur	Remote sensing techniques	Ministry of Agriculture and farmer welfare	Difference between RS and Agriculture department
Wheat	205048	193246	11802
Gram/pulse	40159.5	37198	2961.5
Others	5640.57	4630	1010.57
Total	250848.1	235074	15774.07

*Source: Ministry of Agriculture and farmer welfare. The acreage is expressed in ha*
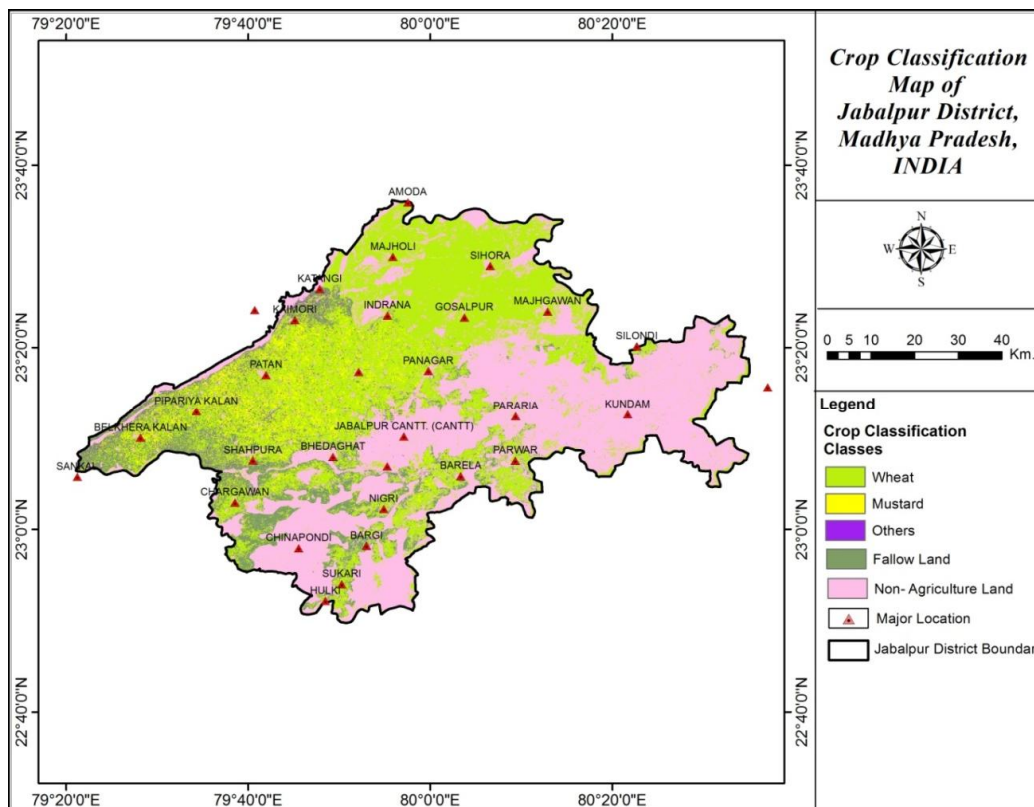
Fig. 4. Crop classification map of Jabalpur district

The refined training statistics generated using the multi-bands data are used for unsupervised classification using maximum likelihood/other parametric classifiers. The digitally classified pixels of study crop and total pixels in the district mask image are used for estimating crop proportion in the district.

3. RESULTS AND DISCUSSION

Sentinel-2 image acquired in the growing season, four bands at 10 m resolutions are stacked and the resultant image has been used for the crop classification. In remote sensing, the accuracy of LULC map is one of the most valuable indicators to determine the quality of the produced map, fitness for a specific application as well as an understanding of error and its implications [13]. In this work, results show that wheat is the major crop of the study area thatthe wheat crop area is 205,048 (ha), 83.07% of the total crop area.gram/ pulses correspond to 36,159.5(ha), 14.64% of the total. The Other crops cover 5,640.57 (ha), which represent 2.28%. Regarding to the performance evaluation, the overall accuracy and overall Kappa Statistics of the classification are 85.71% and 0.819%, respectively.

Pie Chart showing crop area in percentage of wheat , gram and other crops

Others
2%

Gram/Pulse
15%
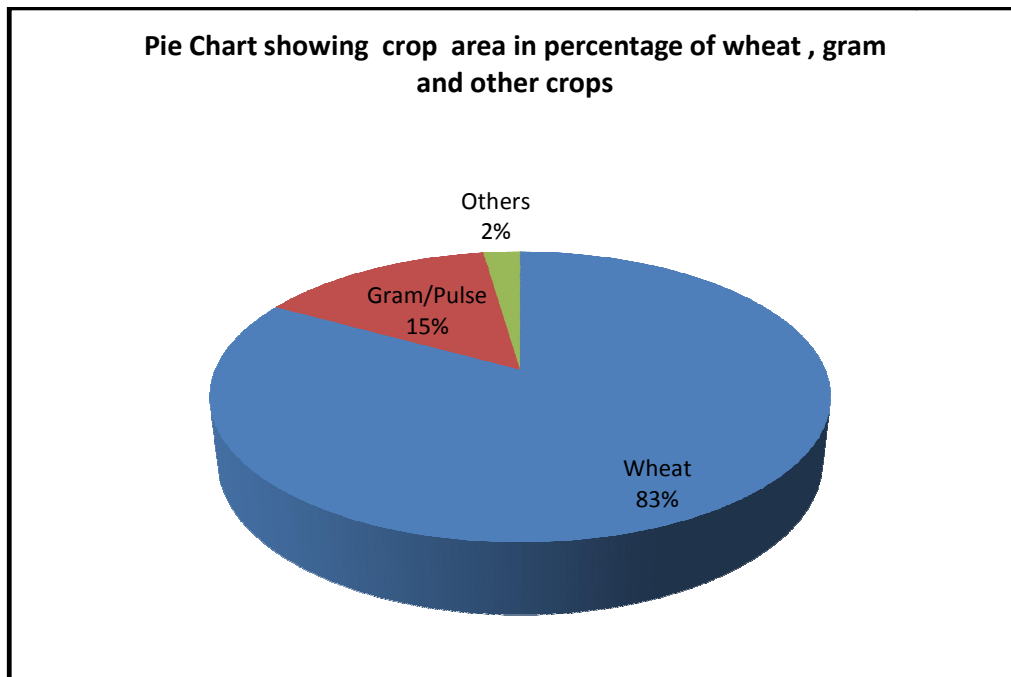
Wheat
83%

Fig. 5. Pie diagram showing the percentage area of wheat, gram and other crops in Jabalpur district

4. CONCLUSION

Remote Sensing and GIS technology have the potential of revolutionizing the detection and characterization of agricultural productivity based on biophysical attributes of crops. . Although RS cannot capture all types of agricultural information, it can reliably provide accurate and timely information to guide agronomic and economic decision-making, if used in Jabalpu area. The study clearly demonstrated that district-level wheat acreage could be reliably estimated using multi-date vegetative growth stage Sentinel data and digital unsupervised classification. The unsupervised classification resulted in a 6.10 percent higher estimation of wheat acreage against the estimation given by the land record commissioner, Jabalpur, Madhya Pradesh.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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