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# MAPPING THE SOWING WINDOWS OF WHEAT IN LUDHIANA DISTRICT USING SENTINEL-2 SATELLITE IMAGES

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## ABSTRACT

Several time series methods have been developed to extract the sowing of wheat from earth observation data but there are few studies in which Sentinel-2 imageries have been used for mapping the sowing dates of wheat in Punjab. Therefore, a study was carried out to evaluate the efficacy of Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 satellite imagery for mapping the sowing windows of wheat in the Ludhiana district of Punjab. The distinct temporal patterns in NDVI values corresponding to different stages of wheat growth cycle resulted in its classification with an overall accuracy of 86%. The NDVI values of wheat were lesser (<0.2) during sowing period followed by a significant increase (>0.5) during vegetative growth stage and a sharp drop after harvesting (<0.2). The wheat sowing area over the three months was in the order: November 2022 (77.2% of the sowing area) > October 2022 (28.0% of the sowing area)> December 2022 (26.8% of the sowing area). This approach presents a valuable tool for informed decision-making regarding the resource allocation and improved agronomic practices.

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**Keywords:** Wheat mapping, NDVI, Sowing cycle & Crop classification.

## INTRODUCTION

Punjab's wheat crop is a significant contributor to the nation's food grain production. The favourable climatic conditions along with soil conditions and agronomic factors create a thriving environment for wheat cultivation in Punjab (Sandhu et al., 2023). The state's high wheat yield is a result of modern farming practices including irrigation and mechanisation. However, identification of sowing dates of wheat is crucial in crop modeling that determines how weather in addition to abiotic and biotic stress will affect wheat yield (Qiao et al., 2023). Remote sensing emerged as a powerful tool providing the invaluable insights into many facets of the wheat cultivation cycle. This technology encompasses diverse methods like multispectral and hyperspectral sensors, and unmanned aerial vehicles (UAVs) to extract the sowing dates of wheat. By leveraging the spectral properties of wheat at different wavelengths, these techniques enable accurate crop classification and the identification of key parameters such as crop health, water stress levels, nutrient deficiencies, and potential pest infestations (Choudhury and Bhattacharya, 2018; Skendzic, et al, 2023). This information empowers farmers and agricultural experts to make informed decisions regarding irrigation scheduling, fertilizer

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application, disease and pest management, ultimately leading to optimized resource utilization and increased crop yields (Lee *et al.*, 2010).

Several studies have demonstrated the effectiveness of remote sensing in various aspects of wheat production (Gao, 2024; Pan et al., 2021). Lobell et al. (2013) used the Moderate Resolution Imaging Spectroradiometer (MODIS) and Satellite Pour l' Observation de la Terre Vegetation (SPOT) sensors to measure the sow dates in the Indian section of the Indo-Gangetic plains. Dinesh kumar et al. (2019) mapped the crop phenology using time series MODIS data in the parts of Tamilnadu. Singh et al. (2022) derived the phonological metrics of crop from Landsat data. Yue et al. (2024) used the Sentinel-2 images for wheat planning and harvesting area in the North China Plain. There are few studies in which Sentinel-2 imageries have been used form mapping the sowing windows of wheat in Punjab. Therefore, a study was carried out to evaluate the efficacy of Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 satellite imagery for mapping the sowing windows of wheat in the Ludhiana district of Punjab.

## MATERIALS AND METHODS

**Study area:** The sowing windows of wheat were extracted in the Ludhiana district of Punjab (**Fig.1).** Ludhiana district is situated in the centre of the Punjab plain region which is devoid of major topographic features and is conspicuously a flat terrain. The major physiographic units are: flood plain, alluvial plain and sand bars or dunes. The elevation of the Ludhiana plain varies from about 268 m in the east to about 216 m in the western part. The topography of the district is shaped by Satluj River and its tributaries. The river course changes from time to time. The total rainfall of the district averages 660 mm (average of 40 years). About 70 per cent of the rainfall is received between July and September and coincides with most of the growth period of the *Kharif* crops. From October to the end of June, generally dry conditions prevail except for a few light showers received owing to westerly depressions. The district represents the extremes of climate. The summer temperatures are severely high, with May to June temperature ranging from 45 $^0$C to 48 $^0$C. The winters are fairly cold, with temperature touching very low on a few days during December to January. Frosts are fairly common during these months.

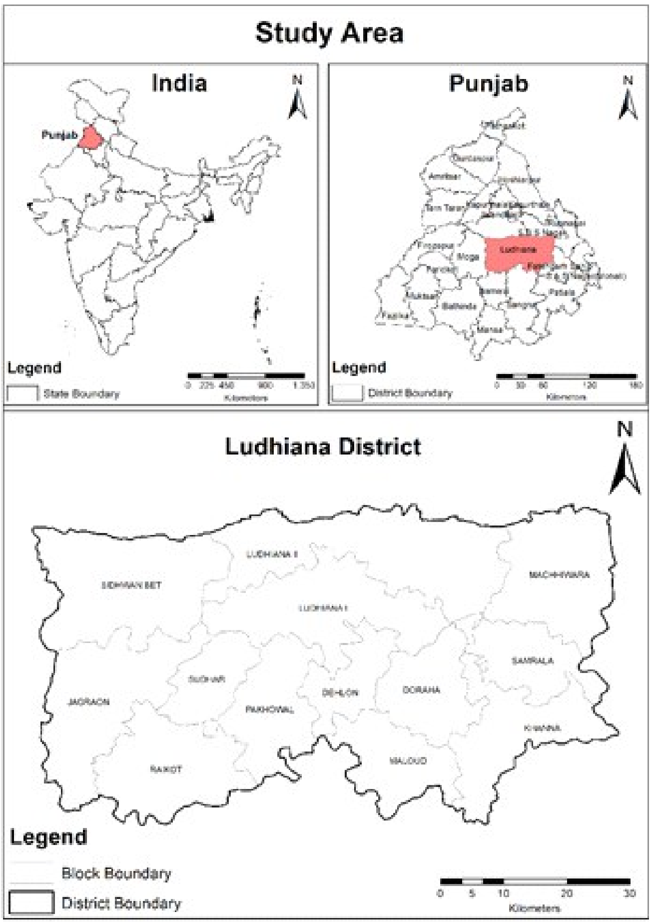


**Fig. 1: Study area.**

Satellite data: This study utilizes data from the Sentinel-2 mission, specifically the Sentinel-2A and Sentinel-2B satellites. These satellites cover vast areas in a single pass and useful for wheat mapping projects on district /block scale. With a 10-meter spatial resolution in the visible and near-infrared (NIR) regions, they provide sufficient detail to distinguish between wheat fields and other land cover types. Their 13 spectral bands capture information across various wavelengths. This information is crucial for differentiating wheat from other vegetation based on its unique spectral signature, which varies across the electromagnetic spectrum throughout its growth cycle. The two Sentinel-2 satellites have a combined revisit period of 5 days. This frequent data acquisition allows for capturing critical changes in wheat crops throughout the growing season.

### Methodology

In this study, Sentinel-2 time series images from November 2022 to April 2023 were used to cover the wheat crop's growth stages from sowing to harvesting seasons. Normalized Difference Vegetation Index (NDVI) was derived from the pre-processed images to understand the spatio-temporal dynamics of the wheat crop, and is calculated using the following formula.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where, NIR is the spectral reflectance in the near-infrared band, and Red is the spectral reflectance in the red band of the multispectral Sentinel-2 satellite image.

Ground-truth locations of wheat fields were collected through field visits in the Ludhiana district to identify the spectral signature of wheat fields and the variation of the spectra. For these locations, the temporal variation of NDVI was computed. A rule-based classification was performed to distinguish from other crops based on the time series NDVI profile.

## RESULTS AND DISCUSSION

### Classification of wheat

In this study, Normalized Difference Vegetation Index (NDVI) analysis showed a distinct temporal patterns for wheat in the Ludhiana district. During the sowing period (late October to November), wheat fields exhibited the lower NDVI values ($< 0.2$) due to sparse vegetation cover. As the crop enters its vegetative growth stage, the NDVI values progressively increase ($> 0.5$), reaching a peak when the leaves and shoots are fully developed. Following harvesting in April and May, NDVI values again drop significantly ($< 0.2$) due to the removal of plant biomass. Using these variations in NDVI values observed at ground-truth locations, a rule-based masking technique was implemented. This technique identified regions exhibiting specific temporal patterns in NDVI: below 0.2 during sowing, above 0.5 during full growth, and below 0.2 after harvest (Fig. 2).

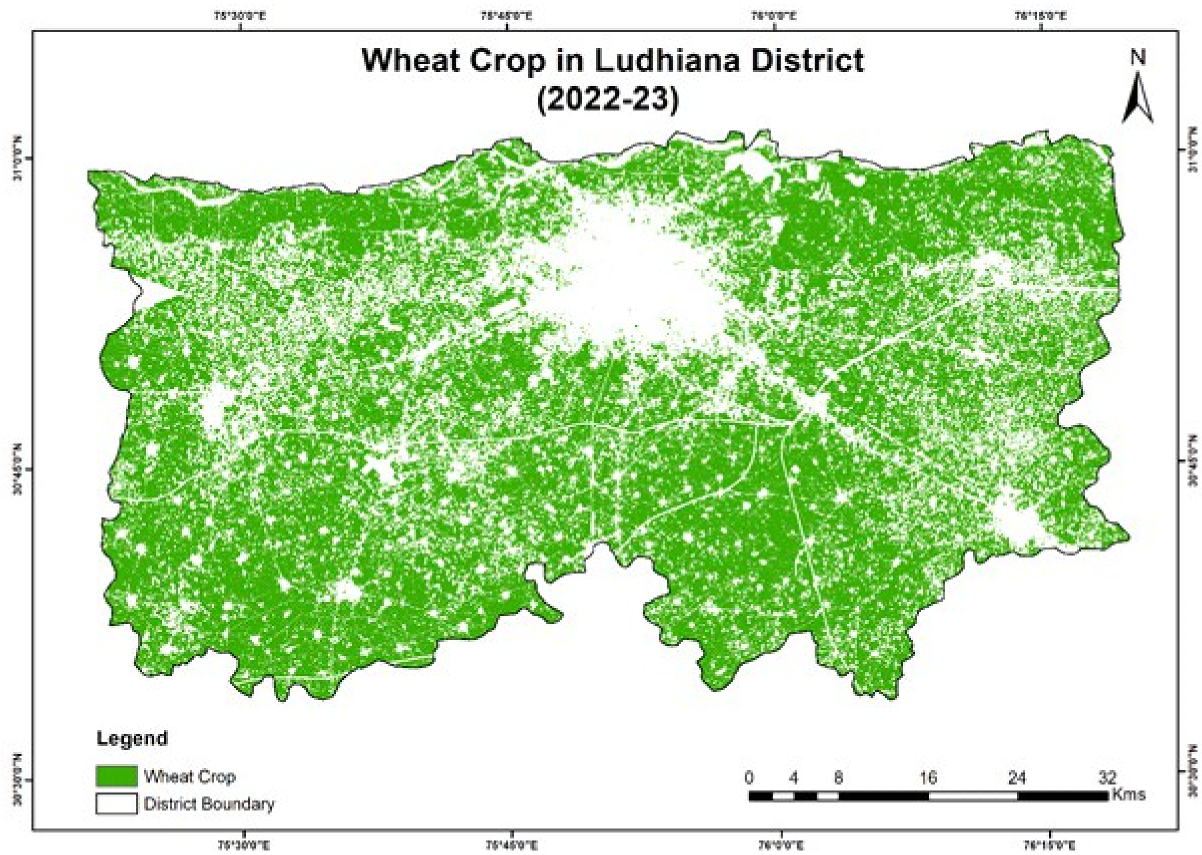


**Fig. 2: Wheat sowing in the Ludhiana district of Punjab during 2022-2023.**

**Cycle-wise sowing dates of Wheat crop:**

Using time-series NDVI data from October to December, the cycle wise sowing data was generated at 10-m spatial resolution for the crop season 2022-2023. Figure 3 showed that wheat sowing started form 1st October 2022 which covered 8% of the sowing area. There was an increase by 4% in sowing area from 11-20 October 2022, however, sowing area decreased by 5.9% between 21 and 30 October 2022. The area under wheat sowing was 27.8% between 1 and 20 November 2022. Highest wheat (49% of the sowing area) sowing took place from 21 to 30 November followed by 28% sowing in between 1 and 10 December 2022 (Fig. 4). The wheat sowing area over the three months was in the order: November 2022 (77.2% of the sowing area) > October 2022 (28.0% of the sowing area)> December 2022 (26.8% of the sowing area). The distinct temporal patterns observed in NDVI values across the wheat sowing over three months showed the crop classification with an overall accuracy of 86%.

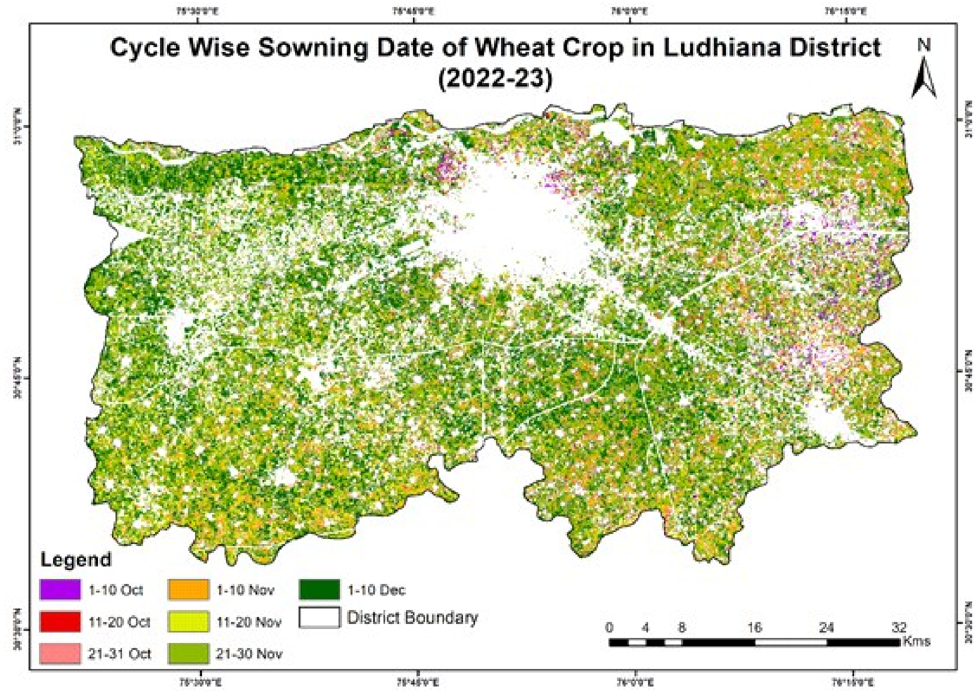


**Fig. 3: Cycle wise wheat sowing in the Ludhiana from October to December 2022.**

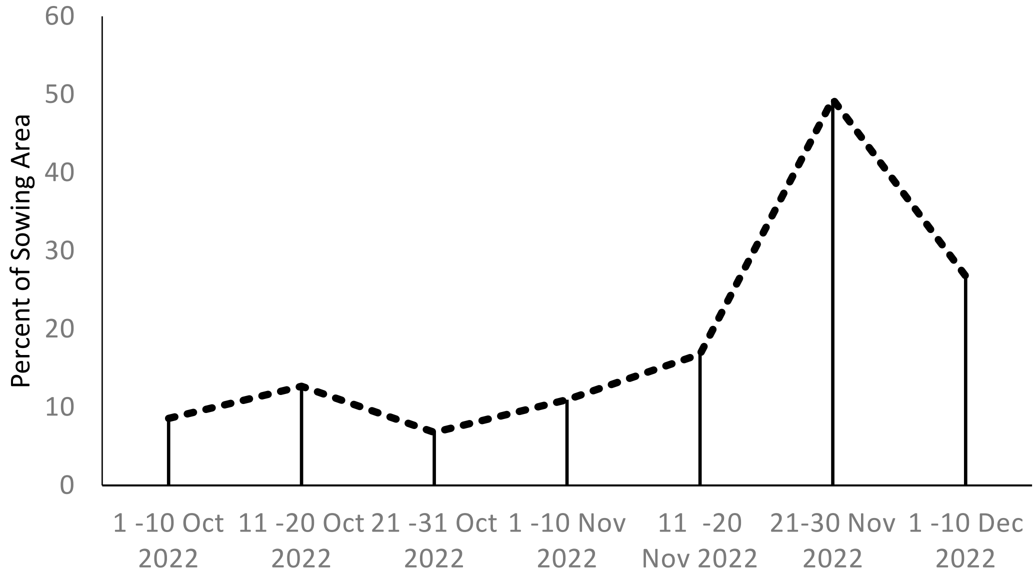


**Fig. 4: Area under wheat sowing in the Ludhiana district of Punjab from October to November of the year 2022.**

## CONCLUSIONS

The results of this study showed the effectiveness of NDVI values extracted from Sentinel-2 satellite data for mapping the sowing dates of wheat in Ludhiana district (Punjab) on spatial scale. The rule-based classification model based on NDVI values provided the accurate mapping and classify the wheat area according to different sowing dates. The maximum sowing area in the district was observed between 1 and 30 November 2022. The replication of this study is useful for planning precision agricultural operations, agronomic practices and understanding the spatio-temporal dynamics of crop in an area.

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### Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and publication of this article.

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