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DETECTING YELLOW RUST OF WHEAT AT VILLAGE LEVEL USING SENTINEL-2 SATELLITE IMAGES

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Research Paper

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ABSTRACT

Yellow rust is a destructive disease that adversely impact the growth and production of wheat. Previous studies shown that the parts of Rupnagar district, the foothill district of Punjab, is the most severely affected area for yellow rust of wheat because climate conditions in this area are favourable for its growth. Therefore, a study was planned to demonstrate the potential of Sentinel-2 images in detecting the yellow rust of wheat at village level (Nangal Nikku and Dukli villages of Rupnagar District of Punjab). Time series Normalized Difference Vegetation Index (NDVI) values from 27 January, 2024 to 08 February, 2024 were extracted from Sentinel-2 images to distinguish the diseased from healthy crop in the two villages. Compared with the NDVI values of healthy wheat, a decrease in NDVI by 17.9 -19.4% was observed in the disease crop during this period. The rule-based classification effectively identified the yellow rust areas of wheat in the two villages. These results showed that Sentinel-2 may be used for detection of diseased crop at village level and this may assist in taking the corrective measures that ultimately contributing to improved crop health and yield sustainability.

No. of Pages: 6 **References: 24**

Keywords: Normalized difference vegetation index, Sentinel-2 data, Yellow rust.

INTRODUCTION:

Wheat is one of the extensively grown crops but highly susceptible to pests and diseases (Yuan *et al.*, 2014). Yellow rust caused by *Puccinia striiformis* f. sp. tritici poses a serious threat to wheat yield and frequently occurs in moderately low temperature and high humid regions (Ren *et al.*, 2021). The distinctive symptom of yellow-colored stripes on wheat leaves, facilitates easy diagnosis. These stripes, typically 2 or 3 mm wide and running parallel to leaf veins, signify the presence of the disease (Nguyen *et al.*, 2023). The farmers usually use the size of the diseased area on the leaves to determine the extent of damage. However, this method is prone to error and may occur in excessive use of pesticides or fails to achieve the optimum level of pest control. Further, this will lower crop productivity and result in economic losses (Wellings, 2011; Sabença *et al.*, 2021; Biel *et al.*, 2021; Chai *et al.*, 2022). Therefore, timely and precise disease monitoring is crucial to mitigate economic losses in farming.

The conventional visual inspection method for detecting wheat yellow rust in the field, has major limitations including small coverage and the inevitable subjectivity of analysts (Zheng *et al.*, 2018;

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Guo et al., 2021). In the recent years, remote sensing technology has emerged as a viable alternative for the identification of diseased crop, offering cost effective monitoring, and allowing better disease control (Moshou et al., 2004; Franke et al., 2005; Su et al., 2018; Su et al., 2019; Abdulridha et al., 2020). The variability in plant pigments and their corresponding spectral signatures allows researchers to employ visible imaging techniques for effective plant disease detection (Ashourloo et al., 2014). Yellow rust induces changes in physiology of plants, altering their photosynthesis patterns accordingly. This alteration is measurable through changes in radiant energy absorption and reflectance rates, detectable by multispectral and hyperspectral satellite imageries (Thirugnana Sambandham et al., 2022, Guo et al., 2020). Previous studies have proven the potential of spectral vegetation indices for detecting the changes in plant physiology, and phenology (Hillnhütter & Mahlein, 2008; Mahlein, et al., 2013; Dutta et al., 2013; Nguyen et al., 2023). Dutta et al. (2013) utilized remote sensing derived indices to identify the yellow rust on wheat in different areas of Punjab. Singh et al. (2023) suggested the use of Sentinel-2 satellite imagery for monitoring yellow rust of wheat. However, there are very few studies in which yellow rust of wheat has been identified at village level. Based on the effectiveness of vegetation indices in sensing physiological changes, the current research was aimed to explore the ability of Sentinel-2 images (Spatial resolution of 10 m in visible and near infrared bands) in determining the yellow rust of wheat in the selected villages of Rupnagar District of Punjab using a rule-based classification approach.

Study Area and Dataset Used

This study was focused on mapping of yellow rust affected wheat in Nangal Nikku and Dukli Villages of Rupnagar District of Punjab as represented in Fig. 1. The Roopngar district is divided into four main physiographic units namely: Siwalik Hills, Valleys, Piedmont plain and Alluvial/Flood plain. This region characterized by diverse landscapes including flood plains, fertile alluvial plains. The river Satluj forms the main drainage system in the area and flows in general from north east towards west. This region experiences distinct seasons, with dominant south-easterly rains between July and September. The remaining months are generally dry with occasional winter showers. The climate exhibits extremes summers reaching up to 48°C and chilly winters dipping to very low levels in December and January.

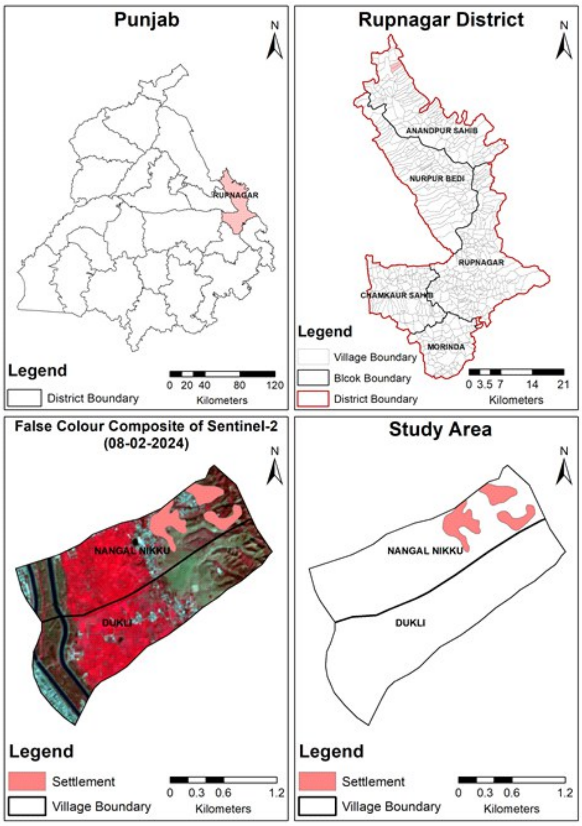

Figure 1: Study area.

The cloud free Sentinel-2 satellite images acquired from November 2023 to February 2024 were used to identify the diseased crop. This satellite offers several key advantages for mapping of biotic stress like vast areas coverage with 10-meter spatial resolution of visible and near infrared bands, which provide sufficient detail to distinguish between stress induced fields. The 13 spectral bands of Sentinel-2 capture information across various wavelengths. This information is crucial for differentiating between stress induced 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. Field survey was conducted in multiple wheat field's locations having yellow rust disease during February, 2023.

Methodology

In this study, Sentinel-2 time series images between November 2023 and February 2024 were used to cover the growth stages of wheat from sowing to disease infestation stage (2023-24). Normalized Difference Vegetation Index (NDVI) was derived from the pre-processed images to understand the spatio-temporal dynamics of the wheat crop. The formula for computing NDVI is:

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

Ground-truth locations of yellow rust affected wheat fields were collected through field visits in the Nangal Nikku and Dukli Villages of Rupnagar District during February 2024. For these locations, the temporal variation of NDVI was computed. A rule-based classification was employed to distinguish between yellow rust affected wheat crops from healthy crops based on the time series NDVI profile. Wheat sowing in the study area typically starts in October to November, while the diseases has been identified in January to February.

Results and Discussion

The false colour composite (FCC) of Sentinel-2 facilitated the visual identification of diseased crops in dark red tone and healthy crops in light red tone. The examples of diseased crop areas are shown with blue boundary and healthy crop areas with white boundary in Fig. 2. The NDVI spectral profile recorded during November, 2023-February, 2024 is shown in Fig. 3. The spectral profile revealed the occurrence of yellow rust in early January 2024 and the disease progressed towards February, 2024. A sudden decline in NDVI values (17.9-19.4%) was observed from 27 January, 2024 to February 8, 2024. This was mainly due to moist climate with high humidity in mountainous region that favored the growth of yellow rust (IMD, 2024; Dutta et al., 2013).

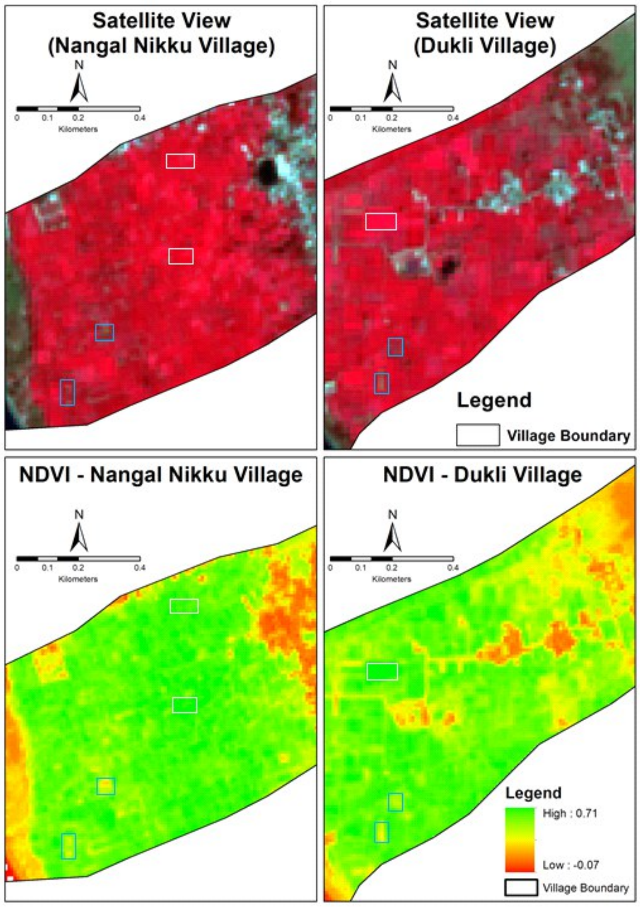

Figure 2 False Colour Composite of Sentinel-2 and NDVI of the study area.

The optimal threshold range of NDVI was obtained based on the trial-and-error method. The wheat pixels having NDVI values greater than 0.5 and lesser than 0.6 are considered as diseased crop, whereas, the wheat pixels with NDVI values greater than or equal to 0.6 were categorized as healthy crop (as represented in Fig. 4). It was found that nearly 51% of the total wheat area in the two villages was affected by yellow rust disease.

In this study, the influence of wind condition was included that likely favor the dispersion of yellow rust spores over long distance (Sánchez Espinosa, 2023). Indian Meteorological Department (IMD) reported

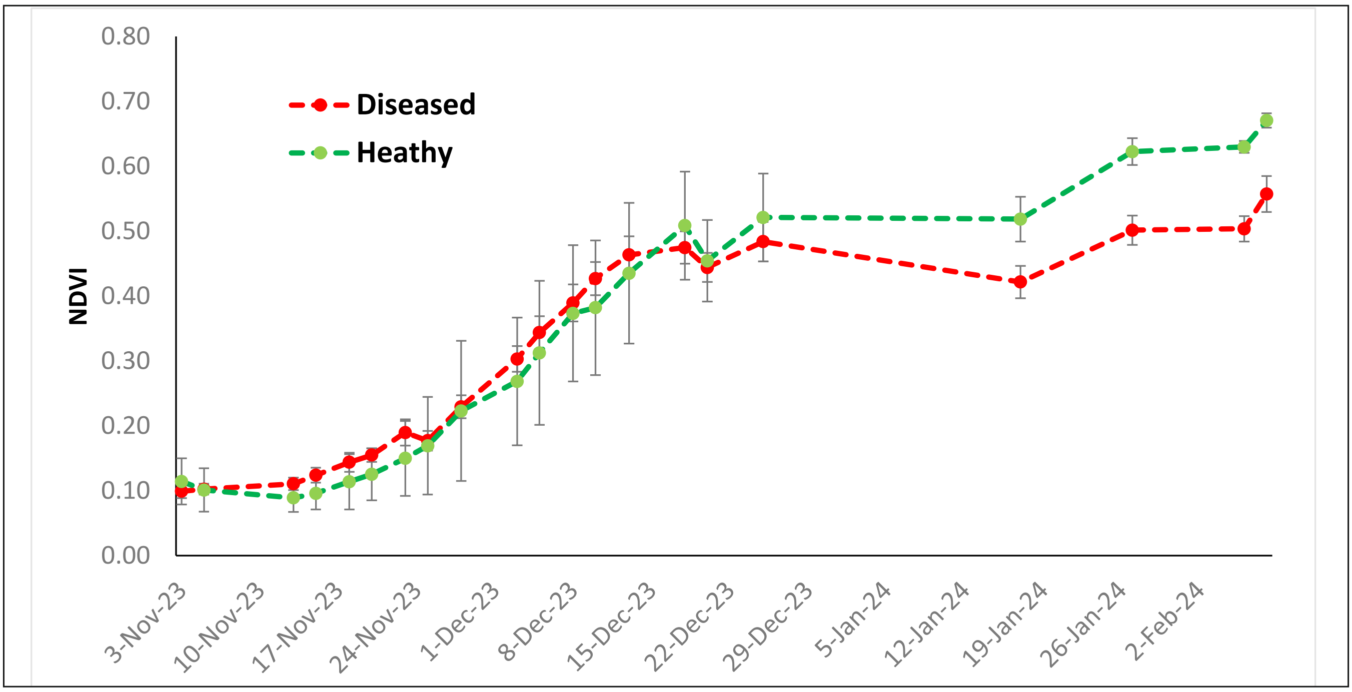

Fig. 3: Spectral profile of NDVI for diseased and healthy crop. Vertical lines indicate standard error of the mean.

strong and chilly surface wave warning conditions over Punjab during January-February, 2024 (IMD, 2024). The wind speed and wind direction data obtained from ERA5 Daily Aggregates (Muñoz Sabater, 2019) showed that the winds speed remained up to 30-40 kmph which contributed to the rapid dispersal of the disease, leading to increased incidence in wheat fields across the district. This, in turn, posed a significant threat to the region's wheat production, potentially resulting in yield losses and economic consequences for farmers.

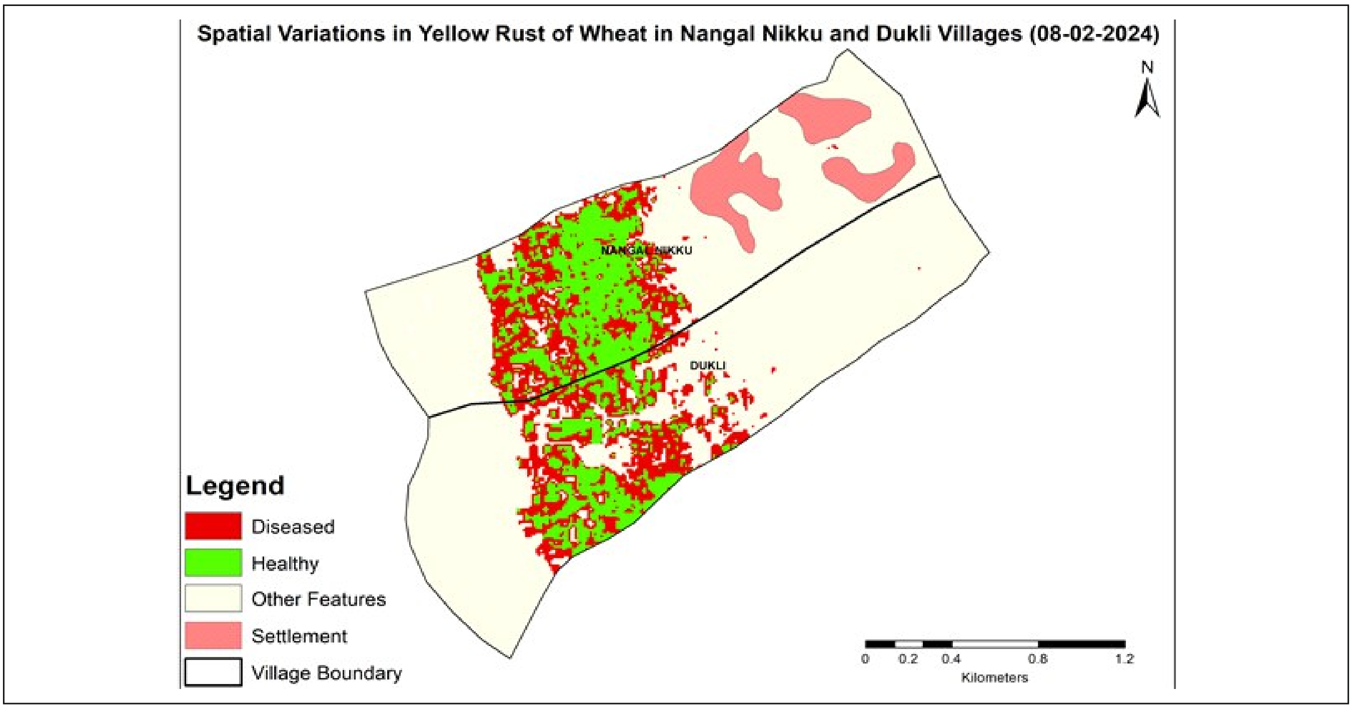

Fig. 4: Classified yellow rust affected and healthy wheat in Nangal Nikku and Dukli Villages of Rupnagar District of Punjab.

CONCLUSIONS

The results of this study showed the efficacy of NDVI time series data derived from Sentinel-2 for detecting yellow rust of wheat and NDVI data provided a clear distinction between healthy and infected areas, supporting its application as an effective tool for early detection and monitoring at village level. Additionally, climatic conditions (i.e., low temperature and high humidity) and wind speed data has greatly influenced the onset and spread of yellow rust. Furthermore, Sentinel-2 images offer a cost-effective solution for large-scale disease monitoring, potentially reducing the economic impact of yellow rust on wheat production. Future research should focus on improving the spatial resolution and incorporating other spectral indices to further refine disease identification and extend its application to other crop diseases.

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