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Monitoring of wheat crop growth at farm level using time series multispectral satellite imagery †

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Abstract: Monitoring of wheat crop growth plays a crucial role in ensuring effective agricultural management and enhancing food security. Valuable insights into the spatial distribution and various growth stages of wheat crop can be obtained through the combination of multi spectral remote sensing datasets, data analysis, and ground-truth verification. This work aims to monitor the wheat crop at the farm level in the Bathinda district of India during the agricultural year 2022-23. It involves collecting and analyzing multispectral satellite data over five selected farmlands in the study region. Preprocessing of the multispectral satellite data is performed including radiometric and atmospheric corrections. The wheat crop's health and growth are examined by utilizing various indices such as Land Surface Water Index (LSWI), Normalized Difference Red Edge (NDRE), and Normalized Difference Vegetation Index (NDVI) retrieved from the time series remote sensing datasets. Furthermore, wheat crop monitoring is performed fortnightly data to encompass its health, moisture levels, and growth stages for individual farmland. Different farmlands have shown varying LSWI, NDRE, and NDVI values. Variations in crop growth and productivity were observed among farmlands due to differences in soil properties and sowing dates. The findings from this study offer valuable insights into the importance of timely sowing, crop health monitoring, irrigation management, and soil suitability in optimizing wheat crop production.

Keywords: Wheat crop; LSWI; NDRE; NDVI; Multi-spectral remote sensing

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1. Introduction

Agriculture forms the foundation of Indian economy and plays a crucial role in driving the country's socioeconomic development [1]. With vast agricultural land that has contributed to its economy for centuries, India stands as one of the world's leading producers not only of wheat and rice but also various other crops [2]. Wheat, being a key food crop, is cultivated under diverse agro-climatic conditions throughout the country. Amongst India's significant agricultural regions, Punjab holds particular importance. Situated in the north-western part of India, it covers an extensive area of approximately 3.4 million hectares, accounting for nearly 45% of the annual cropped area.

Bathinda, one of the largest districts in Punjab, is renowned for its fertile lands and thriving agricultural practices. The district's agricultural landscape is predominantly shaped by crops like wheat, rice, cotton, and sugarcane. Among these crops, wheat holds immense significance as a vital rabi crop in Bathinda's agricultural sector. Its cultivation plays a pivotal role in driving the district's agriculture forward. Therefore, effective monitoring and management of wheat crops are crucial for optimizing productivity and resource allocation [3]. In recent times, the utilization of multispectral satellite imagery has emerged as an invaluable tool for crop monitoring due to its ability to capture a wide range of spectral bands [4,9]. This research paper focuses on leveraging multispectral satellite imagery to monitor wheat crops at the farm level during the agricultural year 2022-23.

2. Materials and Methodology

2.1. Study Area

Bathinda, also known as Bhatinda, is a town in Malwa district in the Indian state of Punjab. It is located at latitude 30.2083° N and longitude 74.9487° E. It has a total area of approximately 3,385 km^2. This area has significant agricultural potential and is often called the "green district" of Punjab.

2.2. Data Collection

Sentinel-2 satellite imagery and other spatial datasets were used for this research work on farm level monitoring [5]. To gather accurate and reliable data, a comprehensive field data collection campaign was carried out in targeted areas within Bathinda district. This extensive collection effort included gathering information about the crops being cultivated, specific crop varieties, as well as recording GPS coordinates of these locations. Moreover, detailed observations were made concerning other competing crops present across the district and were carefully documented alongside field photographs that visually showcase different growth stages of the wheat crop.

2.3. Data Processing and Analysis

The multispectral satellite data were preprocessed that involved radiometric and atmospheric corrections. From the processed imagery, vegetation indices such as NDVI, NDRE, and LSWI were calculated to assess crop health and growth [6,10]. The variations in these indices, both spatially and temporally, were then analyzed to evaluate the performance of each individual farm field for wheat crop [7,8].

2.4. Fortnightly Wheat Crop Monitoring

Fortnightly, the wheat crop monitoring data that encompassed crop health, moisture levels, and growth stages underwent collection for each individual farm field. This valuable dataset was meticulously analyzed to monitor the progress of the crops over time and detect potential fluctuations in their overall health and growth patterns.

3. Results

The comprehensive analysis of multispectral satellite data has yielded intriguing insights into the performance of the five meticulously selected farm fields, each demonstrating distinct characteristics and trends in their crop health and productivity.

3.1. Farm 1 analysis

Upon close examination of the data from Figure 1 (a), consistently exhibited lower values for key vegetation indices such as LSWI, NDRE, and NDVI in Figure 1 (b). These findings suggest that farm 1 experienced comparatively poorer crop performance throughout the monitoring period. The low values of these indices indicate potential challenges in crop health and growth

3.2. Farm 2 analysis

In contrast, presented a more moderate profile when it comes to vegetation indices in Figure 2 (a). The data revealed the values that fall within a mid-range spectrum for these indices, implying an average level of crop performance. While not exhibiting the same robustness as some other farms, farm 2 maintained a steady and consistent performance in its crop health shown in Figure 2 (b).

3.3. Farm 3 analysis

As depicted by the data in Figure 3 (a), displayed a nuanced picture. While it showcased relatively low values for LSWI, which indicates potential water stress, it simultaneously exhibited higher values for NDRE and NDVI shown in Figure 3 (b). These findings suggest that farm 3 experienced specific variations in crop health, potentially indicating adaptability to varying environmental conditions or farming practices.

3.4. Farm 4 analysis

Farm 4 is shown in Figure 4 (a). On the other hand, in Figure 4 (b), stood out with consistently high values for LSWI, NDRE, and NDVI across the entire monitoring period. Such high values in Figure 10, these indices are indicative of robust crop growth, likely driven by effective agricultural practices, favorable environmental conditions, or both.

3.5. Farm 5 analysis

Farm 5 is shown in Figure 5 (a). This farm consistently demonstrated high values for all three vegetation indices. This pattern suggests not only robust crop growth but also exceptional productivity. The combination of high LSWI, NDRE, and NDVI values in Figure 5 (b), implies that farm 5 has managed to optimize its crop health and achieve a high level of agricultural efficiency throughout the monitoring period.

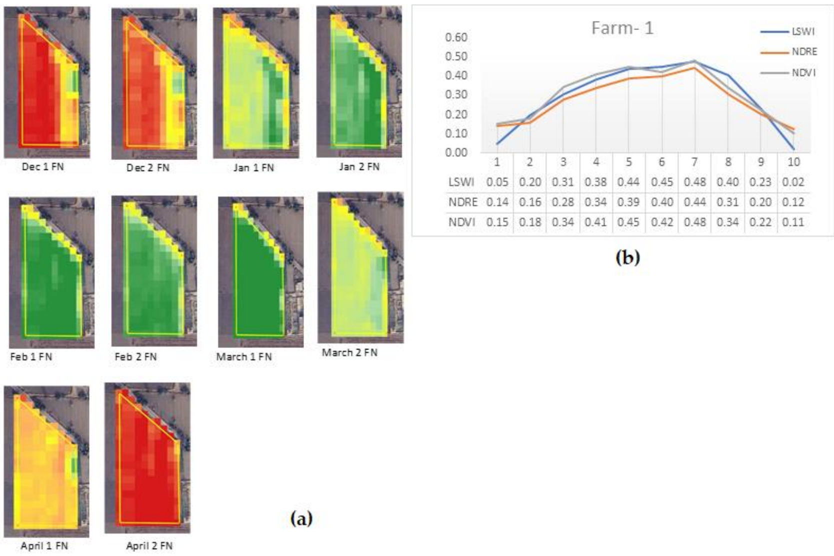

Figure 1. (a) Farm 1; (b) Fortnightly time-series spectral signature curve of Farm 1.

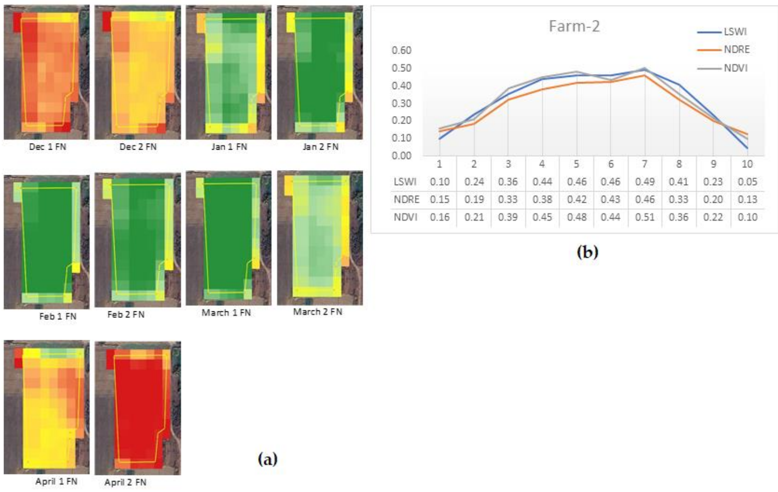

Figure 2. (a) Farm 2; (b) Fortnightly time-series spectral signature curve of Farm 2.

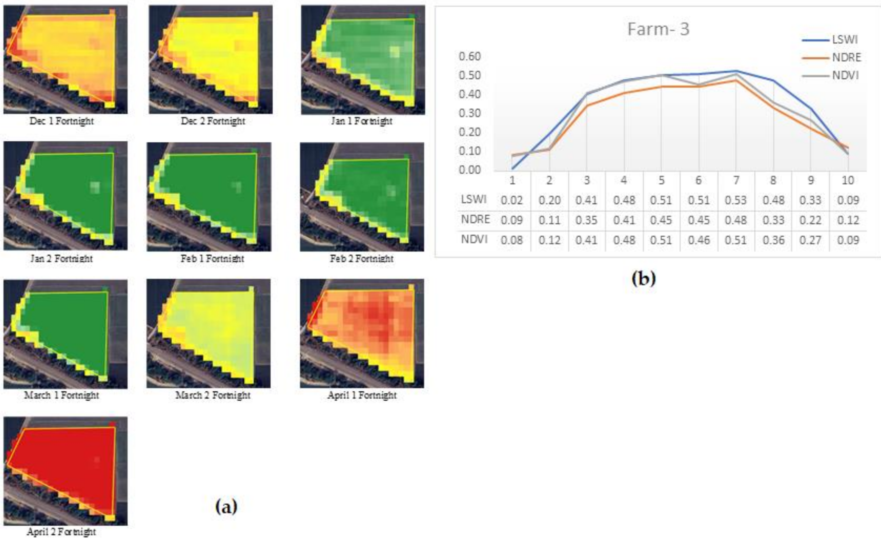

Figure 3. (a) Farm 3; (b) Fortnightly time-series spectral signature curve of Farm 3.

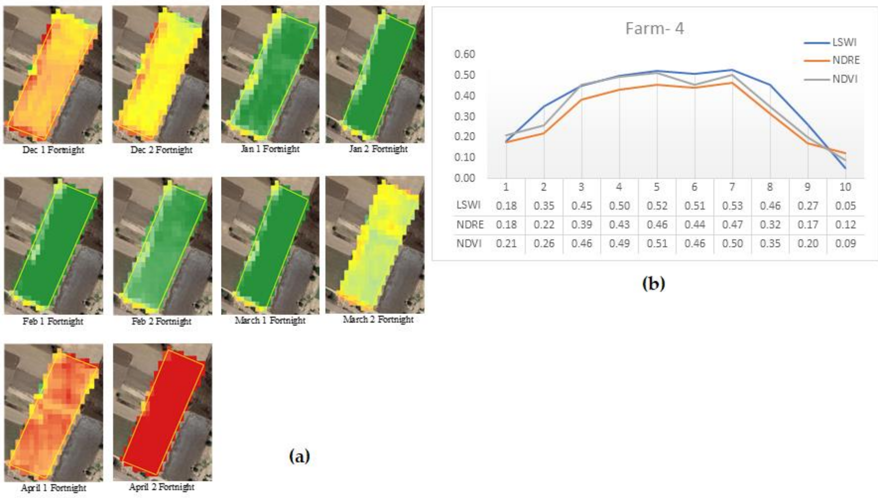

Figure 4. (a) Farm 4; (b) Fortnightly time-series spectral signature curve of Farm 4.

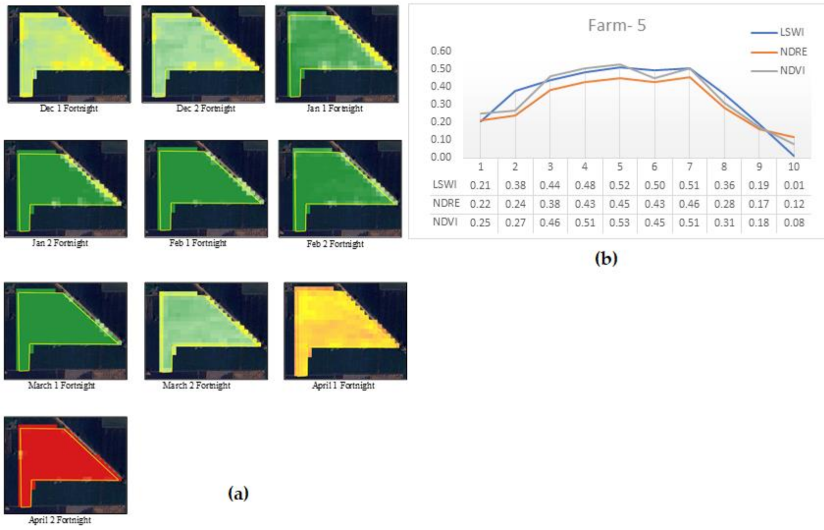

Figure 5. (a) Farm 5; (b) Fortnightly time-series spectral signature curve of Farm 5.

The detailed analysis of multispectral satellite data for these five farm fields has provided valuable insights into their respective crop performances. The diversity in the results highlights the importance of tailoring agricultural strategies to specific conditions and the potential for optimization to enhance crop productivity and overall farm performance. Further investigation and targeted interventions may be required to address the varying challenges and opportunities presented by each of these farms.

4. Discussion

The results of this study emphasize the importance of various factors in effectively managing wheat crop at the farm level. These factors include timely sowing, accurate acreage estimation, crop growth stage classification, health monitoring, harvest status, irrigation management, and soil suitability. Variations in crop growth and productivity were observed among farm fields due to differences in soil properties and sowing dates. Farms that implemented earlier sowing dates generally showed higher vegetation indices, indicating healthier vegetation growth. Furthermore, soil characteristics such as pH level, organic carbon content, and texture played significant roles in determining crop growth and yield [11].

5. Conclusion and future recommendations

The research findings highlight the importance of monitoring wheat crops at the farm level using multispectral satellite imagery. By analyzing vegetation indices and regularly monitoring crop data, valuable insights were gained into crop performance, health, and growth. The study emphasizes the significance of timely sowing, monitoring crop health, managing irrigation effectively, and ensuring soil suitability to optimize wheat crop production in the Bathinda district. Furthermore, adopting smart farming technologies such as drones and robotics can contribute to further enhancing agricultural practices and increasing productivity. Future research should prioritize the integration of this study's findings with advanced machine learning techniques. This will enable accurate and automated monitoring of crop health. Moreover, it is crucial to explore the potential of remote sensing technologies such as hyperspectral imagery and thermal imaging. These technologies can provide a more comprehensive understanding of crop dynamics. Additionally, conducting comparative studies across various regions and crop types can help generalize the findings and identify specific factors influencing crop performance.

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