



HARNESSING SATELLITE DATA FOR SUSTAINABLE AGRICULTURE: AN OVERVIEW OF REMOTE SENSING IN CROP HEALTH MONITORING

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Article History: Received: 10.03.2025 | Accepted: 12.03.2025 | Published: 16.03.2025

Journal DOI: <https://doi.org/10.56602/TDJ>

Article DOI: <https://doi.org/10.56602/TDJ/14.1.1734-1738>

ABSTRACT

Agriculture today faces mounting challenges including climate change, resource depletion, and the growing threat of crop diseases. These factors affect productivity and global food security, demanding innovative and sustainable technologies. Remote sensing, particularly satellite imagery, has emerged as a powerful, cost-effective approach for real-time crop monitoring. Vegetation indices such as the Normalized Difference Vegetation Index (NDVI), derived from satellites like Sentinel-2 and Landsat-8, offer valuable insights into plant vigor, stress, and growth patterns. This paper explores the role of satellite-based remote sensing in crop health monitoring, yield forecasting, and input optimisation. Integrating remote sensing into decision-making enhances precision in irrigation, fertilisation, and pest control, minimising costs and environmental impact. Despite challenges such as cloud interference, spatial resolution limits, and technical barriers, recent advances and open-access data platforms suggest strong potential for widespread adoption. Ultimately, satellite-driven monitoring fosters sustainable, efficient, and resilient agriculture.

Keywords: Remote Sensing, Sustainable Agriculture, NDVI, Sentinel-2, Landsat-8, Precision Agriculture.

INTRODUCTION

Agriculture remains fundamental to human civilization, providing food and livelihoods for billions. However, climate variability, soil degradation, and pest outbreaks threaten productivity and long-term food security. Traditional field-based crop monitoring is often slow, labor-intensive, and prone to human error, limiting scalability. Precision agriculture addresses these issues by leveraging technology for data-driven decision-making.

Among emerging technologies, remote sensing stands out for its scalability and efficiency. Satellites like Sentinel-2 and Landsat-8 capture multi-spectral data that can be processed to compute vegetation indices such as NDVI, a reliable indicator of crop health and stress levels. By providing consistent, large-scale, and near real-time observations, satellite-based monitoring enables early detection of problems and supports precision farming. This paper provides an overview of remote sensing workflows in agriculture, its benefits, challenges, and future directions for sustainable farming systems.

BACKGROUND AND RELATED WORK

Remote sensing enables non-contact observation of Earth’s surface using satellites or aerial sensors [5]. It offers spatially and temporally consistent data for applications like crop mapping, yield estimation, disease detection, and soil property assessment. Vegetation indices are central to agricultural remote sensing. NDVI, introduced by Rouse et al. (1974), measures plant vigor using reflectance in red and near-infrared (NIR) bands:

NDVI = (NIR - Red) / (NIR + Red)

Healthy vegetation reflects more NIR and less red light, producing high NDVI values (≈0.6–1.0). Lower values indicate stress or sparse cover. Studies on major crops like wheat, maize, and rice demonstrate NDVI’s capability to predict biomass, growth stages, and stress. In the U.S., remote sensing supports fertilizer optimization; in India, it aids crop insurance and drought monitoring. Beyond NDVI, hyperspectral sensing captures subtle biochemical variations for early disease and nutrient deficiency detection. Recent studies emphasize fusing multi-sensor data and using machine learning for higher accuracy in yield prediction and stress classification.

METHODOLOGY: A CONCEPTUAL WORKFLOW

Data Collection

Continuous crop monitoring uses data from open-access satellites:

- **Sentinel-2:** 10–20 m resolution, 5-day revisit, ideal for farm-level detail.
- **Landsat-8:** 30 m resolution, 16-day revisit, suitable for regional-scale assessments.

Table 1: Comparison of Sentinel-2 and Landsat-8 Satellite Missions.

Feature	Sentinel-2 (A/B)	Landsat-8
Spatial Resolution	10m, 20m, 60m	15m (Pan), 30m, 100m (Thermal)
Temporal Resolution	5 days (with two satellites)	16 days
NDVI Bands	Red (B4), NIR (B8)	Red (B4), NIR (B5)
Data Access	Free & Open	Free & Open

Pre-Processing

Raw imagery requires corrections for analytical accuracy:

- **Cloud Masking:** Removes cloud/shadow pixels that distort NDVI.
- **Atmospheric Correction:** Converts top-of-atmosphere reflectance to true surface reflectance by mitigating dust and aerosol effects.

Index Calculation and Visualization

NDVI is computed per pixel, and visualized via color gradients (Table 2).

Table 2: NDVI Interpretation for Crop Health.

NDVI Range	Color Code	Interpretation
0.6–1.0	Dark Green	Healthy vegetation
0.2–0.5	Yellow-Green	Moderate stress
0.1–0.2	Red/Brown	Severe stress
<0.1	Grey	Non-vegetated

Decision Support

NDVI-driven insights guide: irrigation scheduling, variable-rate fertilizer management, and yield forecasting. This workflow translates raw imagery into actionable intelligence for sustainable farming.

Results and Discussion

NDVI imagery differentiates healthy from stressed vegetation, enabling resource-efficient interventions. Farmers can target water and fertilizer inputs, reducing waste and environmental harm. Low NDVI patches often indicate disease or pest outbreaks, allowing for early, localized action. At regional scales, remote sensing supports food security through crop area estimation, yield prediction, drought monitoring, and disaster assessment. Such large-scale, objective data empower evidence-based agricultural policymaking.

Limitations and Challenges

Key constraints include:

- **Cloud Cover:** Blocks optical data, especially in monsoon regions.
- **Resolution:** Sentinel (10m) and Landsat (30m) may miss small-field details.
- **Technical Barriers:** Require GIS expertise and processing tools like Google Earth Engine.
- **NDVI Saturation:** In dense canopies, NDVI approaches a maximum value, reducing sensitivity. Future efforts must enhance accessibility and integrate multi-sensor data to overcome these limits [15].

Future Scope

Emerging trends aim to improve precision and usability:

AI & Machine Learning: Deep learning models classify crop types, forecast yields, and detect disease before visible symptoms [10, 16].

Data Fusion: Integrating optical, radar, and drone data provides robust all-weather monitoring.

User-friendly Platforms: Mobile apps converting satellite analytics into farmer-ready advisories will democratize access.

Advanced Indices: Hyperspectral and thermal data enable nutrient-level monitoring and early stress detection [17].

These innovations will further anchor remote sensing in sustainable, climate-smart agriculture.

CONCLUSION

Remote sensing is transforming agriculture from traditional observation to intelligent management. NDVI-based monitoring offers scalable, cost-effective solutions for detecting crop stress and optimizing resource use. Despite challenges of cloud cover and resolution, rapid advancements in AI and sensor fusion are bridging these gaps. Satellite-driven monitoring thus stands as a cornerstone for achieving global food security through sustainable and data-driven agriculture.

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