



CROP HEALTH MONITRING IN DRONE TECHNOLOGY

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Introduction

In the present scenario, the need for drone technology and its applications are increasing day by day. In agriculture, the importance of drones is also growing steadily. Initially, drones were mainly used for spraying operations; however, today they are being utilized for a wide range of agricultural applications. Apart from spraying, drones are widely used for crop monitoring and crop health assessment.

They help in observing crop growth conditions, identifying stress, detecting pest and disease incidence, and assessing overall crop health at an early stage. This article discusses the importance of drones in agriculture and explains how drone technology is used for crop monitoring and crop health monitoring.

Drone Data Acquisition

A drone is flown at a specific altitude over the field to capture images of the crop area. Depending on the purpose, different sensors such as RGB, multispectral, thermal, hyperspectral, and LiDAR can be mounted on the drone to acquire detailed images.

These images are processed using appropriate image processing techniques, and vegetation indices are developed from the processed data.

Drone Indices

Sensors and Technologies Used in Agricultural Drones

Agricultural drones are integrated with advanced sensing technologies that enable precise monitoring of crop health and field conditions. These sensors collect multi-dimensional data essential for modern precision agriculture.

Multispectral Cameras

Multispectral cameras capture images across specific wavelength bands beyond the visible spectrum, including near-infrared regions. These sensors are widely used to generate vegetation indices such as NDVI, which help assess crop vigour, stress, and overall health. Multispectral data is essential for identifying nutrient deficiencies and early-stage crop stress.

Hyperspectral Sensors

Hyperspectral sensors collect data across numerous narrow spectral bands, providing detailed information on plant biochemical properties.

This high spectral resolution enables precise identification of crop species, nutrient status, disease symptoms, and stress factors. Hyperspectral sensing is particularly valuable for advanced crop health analysis and research-driven precision farming.

Thermal Imaging Sensors

Thermal cameras measure surface temperature variations in crops and soil. These temperature differences provide valuable insights into crop water stress, irrigation efficiency, and plant health. Thermal data helps in identifying areas affected by moisture stress or pest-related damage, supporting site-specific water and crop management practices.

LiDAR (Light Detection and Ranging):

LiDAR technology uses laser pulses to generate accurate three-dimensional representations of agricultural fields. It is highly effective for analyzing crop height, canopy structure, and field topography. Although LiDAR-equipped drones are relatively expensive, they offer unmatched accuracy for terrain analysis, biomass estimation, and crop structural assessment.

RGB Sensor Indices

RGB Sensor Indices		
Indices	Application	Formula
Excess Green Index (ExG)	Highlights green vegetation	$ExG=2G-R-B$
Green-Red Vegetation Index (GRVI)	Crop vigour assessment	$GRVI=G+RG-R$
Visible Atmospherically Resistant Index (VARI)	Vegetation monitoring under variable light	$VARI=G+R-BG-R$
Triangular Greenness Index (TGI)	Chlorophyll estimation (RGB-based)	Chlorophyll estimation

Multispectral Sensor Indices		
Indices	Application	Formula
NDVI (Normalized Difference Vegetation Index)	Overall crop vigor and biomass	$NDVI=NIR+RNIR-R$
GNDVI (Green NDVI)	Nitrogen and chlorophyll status	$GNDVI=NIR+GNIR-G$
NDRE (Normalized Difference Red Edge Index)-	Stress detection in dense crops	$NDRE=NIR+RENIR-RE$
SAVI (Soil Adjusted Vegetation Index)	Sparse vegetation conditions	$SAVI=(NIR+R+L)(NIR-R) \times (1+L)$ (where $L=0.5$)

Thermal Sensor Indices		
Indices	Application	Formula

Crop Water Stress Index (CWSI)	Plant water stress detection	$CWSI = T_{dry} - T_{wet} - T_c$ where: T_c = Canopy temperature T_{wet} = Fully transpiring canopy temperature T_{dry} = Non-transpiring canopy temperature
Thermal Stress Index (TSI)	Canopy temperature-based stress	$TSI = T_c - T_a$ Where: T_c = Canopy temperature (°C or K) T_a = Air temperature (°C or K)
Normalized Difference Temperature Index (NDTI)	Relative temperature variation	$NDTI = T_c + T_s - T_s$ Where: T_c = Canopy temperature T_s = Soil or reference surface temperature
Hyperspectral Sensor Indices		
Indices	Application	Formula
Red Edge Position (REP)-	Chlorophyll concentration	
Photochemical Reflectance Index (PRI)	Photosynthetic efficiency	$PRI = \frac{R_{531} + R_{570}}{R_{531} - R_{570}}$
Water Band Index (WBI)-	Plant water content	$WBI = \frac{R_{970}}{R_{900}}$
Structure Insensitive Pigment Index (SIPI)-	Pigment stress and leaf damage	$SIPI = \frac{(NIR - R)}{(NIR - B)}$
Disease Water Stress Index (DWSI)-	Disease-related stress	$DWSI = T_{dry} - T_{wet} - T_c$ Where: T_c = Crop canopy temperature (from thermal imagery) T_{wet} = Temperature of a fully transpiring (well-watered, healthy) canopy T_{dry} = Temperature of a non-transpiring (severely stressed or diseased) canopy.

LiDAR-Derived Indices / Metrics - (Structural and 3D crop information)

- **Canopy Height Model (CHM)**- Crop height and growth analysis
- **Canopy Cover (%)**-Plant density estimation
- **Leaf Area Density (LAD)**-Biomass estimation
- **Vegetation Volume Index (VVI)**- Crop structure and vigour

By generating such indices, farmers and field officers can easily understand field variability and crop condition at an early stage. These indices convert complex image data into simple maps that clearly indicate healthy and stressed crop zones. As a result, decision-making at the field level becomes faster and more accurate. Nowadays, many users have started adopting vegetation and thermal indices for routine crop monitoring because they provide reliable and timely information. The major advantages include reduced field visits, early identification of stress, efficient input management, and cost savings. Overall, the use of drone-derived indices supports precision agriculture by enabling site-specific interventions and improving crop productivity.

Applications of Drones in Crop Monitoring

Drones have significantly transformed the way farmers monitor crop performance, health, and productivity. By providing real-time, high-resolution data, drone technology supports timely decision-making and improves overall farm management efficiency. The use of drones in agriculture has expanded beyond basic observation to include detailed analysis of crop and field conditions.

Enhanced Crop Monitoring

Drones equipped with advanced imaging systems enable comprehensive

monitoring of crop health. High-resolution aerial imagery helps in identifying pest infestations, crop diseases, nutrient deficiencies, and uneven crop growth at an early stage. This aerial view also makes it easier to detect bare patches and stress-prone zones within the field, especially during critical growth stages, allowing timely corrective actions.

Early Pest Detection

Pest infestations can cause severe crop damage if not detected early. Drone-based monitoring using RGB and multispectral sensors helps identify abnormal crop patterns associated with pest attacks before visible symptoms spread across the field. Early detection allows farmers to adopt targeted pest management strategies, reducing crop losses and minimizing excessive pesticide use.

Identification of Crop Diseases

Drones play a crucial role in the early identification of crop diseases by detecting changes in leaf colour, canopy structure, and growth patterns. These stress indicators, often invisible to the naked eye at initial stages, can be accurately identified using drone imagery. Early diagnosis helps prevent disease spread and supports timely application of control measures.

Monitoring Soil Moisture and Water Stress

Efficient water management is essential for sustainable agriculture. Thermal and multispectral sensors mounted on drones are used to assess soil moisture conditions and crop water stress. By identifying water-stressed areas within the field, farmers can optimize irrigation scheduling, detect leakages, and improve water-use efficiency while conserving valuable water resources.

Crop Yield Estimation

Drone-derived data combined with analytical models enables accurate crop yield

estimation. High-resolution imagery supports better assessment of crop biomass and growth variability, reducing errors associated with conventional yield estimation methods. This information assists farmers in planning harvesting operations, storage requirements, and market strategies. Additionally, three-dimensional crop models generated from drone data support precise, location-specific harvesting decisions.

Weed Detection and Management

Drones are highly effective in detecting weed infestations by analyzing spatial variations in crop reflectance. Weed hotspots can be accurately mapped using high-resolution imagery, allowing farmers to apply herbicides only in affected areas. This targeted approach reduces chemical usage, lowers production costs, and minimizes environmental impact.

Advanced Features and Data Collection

In addition to sensor systems, agricultural drones are equipped with GPS-enabled navigation systems that support automated flight planning and precise geo-referencing of collected data. Many advanced drones incorporate real-time kinematic (RTK) positioning systems to enhance spatial accuracy. The integration of RGB, multispectral, thermal, and LiDAR sensors within a single platform allows efficient data collection and supports real-time, high-resolution crop monitoring for precision agriculture applications.

Benefits of Using Drones in Agriculture

Drones enable fast and efficient monitoring of crop health, helping farmers detect pests, diseases, and stress at an early stage. They save time and labour, reduce input costs through precise application of fertilizers and pesticides, and support better decision-making using accurate, real-time field data. Overall, drone technology improves productivity and promotes

sustainable and precision-based farming practices.

Conclusion

While drones offer significant advantages for crop monitoring and precision agriculture, their adoption is limited by technical, financial, regulatory, and operational challenges. Short battery life, high costs, the need for specialized skills, and legal restrictions can hinder widespread use. Additionally, safety, privacy concerns, and managing realistic expectations remain critical. Overcoming these challenges through training, affordable technology, and supportive policies is essential to fully realize the potential of drones in modern agriculture.