



INFRARED THERMAL IMAGING IN AGRICULTURE

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Introduction

Infrared thermal imaging is a sophisticated technique that generates quantitative radiometric digital images of objects within the thermal infrared wavelength range, typically between 0.8 and 15 μm . This method not only offers qualitative visualization but also enables precise measurement of surface temperatures. Its applications in agriculture are extensive, encompassing soil water stress estimation, crop water stress monitoring, water system planning, plant disease identification, and locating farming plastic waste. The thermal imaging framework typically includes a thermal camera equipped with an image acquisition system, a signal processing unit, and infrared detectors. The emitted infrared radiation from objects is absorbed by the detector, converted into electrical signals, and processed into thermal images. Thermal imaging devices are categorized into two types: cooled and uncooled, with performance evaluated based on image resolution, scanning speed, and thermal sensitivity.

Applications of Thermal Imaging in Agriculture

The reflectance spectrum qualities of vegetation depend heavily on leaf properties, with energy reflectance at specific wavelengths determined by leaf thickness and pigmentation. Agricultural applications of thermal imaging are classified into several sections: irrigation scheduling, crop maturity and yield mapping, soil properties mapping, field tile mapping, agricultural plastic waste estimation, crop residue cover and tillage mapping, and plant disease detection. Each of these applications utilizes the unique properties of thermal imaging to enhance agricultural practices.

Irrigation Scheduling

Proper irrigation is vital for optimal agricultural production, especially in areas where in-season rainfall is insufficient. Thermal infrared (TIR) imaging is more sensitive to water stress than visible, NIR, or SWIR wavelengths. When plants experience water stress, their stomata close, leading to increased leaf temperature. Thermal imaging can effectively monitor stomatal responses, canopy temperature, and evapotranspiration rates, providing a basis for precision irrigation scheduling. Innovative research combines TIR with other methods, such as hyperspectral indices and fluorescence, to enhance irrigation management. These approaches enable remote sensing-based irrigation scheduling, focusing on plant-emitted signals rather than soil signals.

Crop Maturity and Yield Mapping

Accurate crop yield estimation is essential for agricultural planning and decision-making. Thermal imaging can improve yield predictions by analyzing temperature differences between plant foliage and ambient air. Studies have shown a strong correlation between thermal data and yield, particularly in wheat. Advanced algorithms now combine thermal and hyperspectral data to estimate fruit counts and sizes, enhancing yield forecasting accuracy for crops like apples. By integrating thermal imaging with other remote sensing tools, farmers can better predict crop maturity and yield, leading to more efficient harvesting and resource allocation.

Soil Properties and Field Tile Mapping

Thermal imaging is also utilized in mapping soil properties and field tiles. The technique helps in identifying variations in soil moisture content and salinity, which are critical for

crop health. By detecting temperature differences, thermal imaging can reveal underlying field tiles, aiding in drainage planning and soil management. This application ensures that fields are properly drained, reducing waterlogging risks and improving soil conditions for plant growth.

Agricultural Plastic Waste Estimation

Locating and estimating agricultural plastic waste is another significant application of thermal imaging. Plastic waste in fields can hinder crop growth and soil health. Thermal imaging can detect plastic materials due to their distinct thermal properties compared to the surrounding soil and vegetation. By identifying these materials, farmers can remove plastic waste more efficiently, promoting better agricultural practices and environmental sustainability.

Crop Residue Cover and Tillage Mapping

Thermal imaging plays a crucial role in mapping crop residue cover and tillage practices. Residue cover affects soil temperature and moisture retention, influencing crop growth. Thermal images can distinguish between bare soil and residue-covered areas, providing insights into tillage practices and their impacts on soil conservation. This information helps farmers adopt conservation tillage methods, reducing soil erosion and enhancing water retention.

Plant Disease Detection

Thermal infrared imaging is invaluable for the pre-symptomatic detection of plant diseases and pathogens. It can identify physiological changes before visible symptoms appear, such as altered transpiration rates and leaf temperatures. For example, thermal imaging has been used to detect downy mildew in cucumbers and scab disease in apples, showing the technique's potential in disease quantification and management. By monitoring pathogen development, thermal imaging becomes a critical tool for early detection and prevention of biotic stresses, reducing crop losses and improving overall plant health.

Nursery Monitoring

In nurseries, early detection of seed quality and monitoring are crucial. Traditional methods for seed viability testing are often destructive, time-consuming, and labor-intensive. Infrared thermography, however, can detect subtle temperature changes linked to seed viability, physical damage, and physiological disorders. By measuring thermal profiles, viable seeds can be distinguished from non-viable ones, aiding in evaluating growth processes in nurseries and greenhouses. This non-invasive technique enhances seed selection and nursery management, improving overall crop production quality.

Soil Salinity Detection

Soil salinity is a significant factor affecting crop growth and regional productivity. Thermal imaging can diagnose salinity stress early by detecting temperature differences in plants subjected to varying salinity levels. For instance, thermography has been used to monitor ornamental crops' responses to salinity, demonstrating its utility in diagnosing saline stress with high accuracy and resolution. By identifying salinity-affected areas, farmers can implement appropriate soil management practices to mitigate salinity's adverse effects on crops.

Conclusion

Infrared thermal imaging is a transformative technology in agriculture, offering precise, non-invasive methods for monitoring various aspects of crop and soil health. Its applications range from irrigation scheduling and soil salinity detection to early disease diagnosis and yield forecasting. By leveraging thermal imaging, farmers can improve resource management, enhance crop productivity, and implement more sustainable agricultural practices. As the technology advances, its integration with other remote sensing tools will further enhance its utility, making it an indispensable asset in modern agriculture.