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Integrating Remote Sensing with IoT for Crop Health Monitoring, Land Mapping, and Precision Agriculture

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Abstract

The integration of Remote Sensing and Internet of Things (IoT) technologies in precision agriculture represents a transformative shift towards more efficient, sustainable, and data-driven farming practices. By combining high-resolution satellite imagery, UAV-based sensors, and real-time IoT monitoring systems, this chapter explores the synergies between these technologies for enhancing crop health monitoring, land mapping, and overall agricultural management. Remote sensing facilitates large-scale monitoring of environmental variables such as soil moisture, temperature, and vegetation health, while IoT devices provide continuous, localized data on critical factors such as soil pH, nutrient levels, and weather conditions. The integration of these data streams enables more accurate early detection of crop stress, pest outbreaks, nutrient deficiencies, and land degradation, facilitating timely interventions that reduce resource use and environmental impact. Furthermore, the application of artificial intelligence (AI) and machine learning (ML) models to analyze and interpret the vast amounts of data collected from both remote sensing and IoT systems is discussed, highlighting how these technologies can drive predictive analytics, optimize resource allocation, and support decision-making processes. Key challenges, including data interoperability, energy efficiency, and the adoption of technology by smallholder farmers, are also addressed, offering solutions to overcome these barriers. By showcasing real-world case studies and emerging trends, this chapter provides a comprehensive understanding of how integrated remote sensing and IoT technologies are reshaping the landscape of modern agriculture.

Keywords: Precision Agriculture, Remote Sensing, Internet of Things (IoT), Crop Health Monitoring, Artificial Intelligence (AI), Land Degradation.

Introduction

The agricultural sector is undergoing a profound transformation with the advent of advanced technologies aimed at improving productivity, sustainability, and efficiency [1]. Among the most promising innovations are Remote Sensing and Internet of Things (IoT) technologies, which, when integrated, offer powerful solutions for modern agriculture. Remote sensing [2], through the use of satellite imagery, UAVs, and other aerial sensors, allows farmers and agronomists to observe and monitor vast areas of agricultural land with high precision [3]. These technologies capture detailed information about crop health, soil conditions, and environmental variables, providing

valuable insights for effective land management [4]. IoT, on the other hand, enables continuous, real-time monitoring through a network of sensors placed in the field, offering granular data on soil moisture, temperature, nutrient levels, and weather patterns. The integration of these two technologies creates a comprehensive system for real-time data collection, processing, and analysis, empowering farmers to make more informed decisions and optimize resource use. This convergence of remote sensing and IoT in precision agriculture is reshaping the landscape of farming, enabling smarter and more sustainable practices [5].

A significant benefit of integrating remote sensing and IoT in agriculture is the ability to monitor crop health and land conditions more effectively [6]. Remote sensing provides high-resolution, large-scale imagery that captures the physical and spectral characteristics of crops [7]. By analyzing changes in vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), remote sensing technologies can detect early signs of crop stress, pest infestations, or nutrient deficiencies [8]. IoT sensors further enhance this capability by providing real-time data on environmental factors, such as soil moisture and temperature, which influence plant growth [9]. Together, these technologies enable farmers to detect and address problems at the earliest stages, reducing the need for broad-spectrum interventions and minimizing the use of pesticides, fertilizers, and water. This targeted approach not only enhances crop health but also promotes environmental sustainability by reducing resource waste and minimizing the negative impacts of agricultural practices [10].

In addition to crop health monitoring, remote sensing and IoT play a critical role in land mapping and soil health assessment [11]. Remote sensing technologies, including multispectral and hyperspectral imaging, offer valuable insights into soil properties, vegetation cover, and land topography [12]. By using this data, farmers can assess soil fertility, identify areas prone to erosion, and track changes in land use over time [13]. IoT sensors placed in the field can complement remote sensing data by continuously measuring soil moisture, pH levels, and other important soil attributes. Together, these technologies enable the creation of detailed soil maps that guide farmers in optimizing irrigation schedules, improving soil health, and managing crop rotation strategies [14]. Moreover, the integration of remote sensing and IoT allows for real-time monitoring of land degradation, enabling farmers to detect early signs of soil erosion, compaction, or salinization, and take corrective actions before these issues lead to significant productivity losses. This comprehensive approach to land management supports sustainable agricultural practices that balance productivity with environmental preservation [15].