Journal of Environmental Science International
33(7); 547~552; July 2024

pISSN: 1225-4517 eISSN: 2287-3503
https://doi.org/10.5322/JESI.2024.33.7.547

REVIEW

Utilization of Satellite Technologies for Agriculture

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Abstract

Satellite technology has emerged as a powerful tool in modern agriculture, offering capabilities for Earth observation, land-use pattern analysis, crop productivity assessment, and natural disaster prevention. This mini-review provides a concise overview of the applications and benefits of satellite technologies in agriculture. It discusses how satellite imagery enables the monitoring of crop health, identification of land-use patterns, evaluation of crop productivity, and mitigation of natural disasters. Farmers and policymakers can make informed decisions to optimize agricultural practices, enhance food security, and promote sustainable agriculture by leveraging satellite data. Integrating satellite technology with other advancements, such as artificial intelligence and precision farming techniques, holds promise for further revolutionizing the agricultural sector. Overall, satellite technology has immense potential for improving agricultural efficiency, resilience, and sustainability in the face of evolving environmental challenges.

Key words : Satellite, Precision agriculture, Remote sensing, Field management, Crops

1. Introduction

Agriculture is a crucial industry that is vital in human survival and development. Enhancing food production and agricultural productivity is an ongoing research area, particularly in response to rapid population growth and the need to ensure food security. In recent decades, advancements in satellite technology have brought about revolutionary changes in the agricultural sector (Nakalembe et al., 2021). Satellite technology has been applied to various agricultural activities, including Earth observation and monitoring, land use pattern analysis, crop productivity assessment, and natural disaster prevention. They play important roles in improving agricultural productivity and protecting crop health and safety.

The aim of this review was to comprehensively investigate the application of satellite technology in agriculture and discuss the latest research trends and technological advancements. First, it introduces the satellite imaging and remote sensing technologies used in agriculture and analyzes the characteristics, advantages, and disadvantages of each technology. Second, it ex-

Received 4 June, 2024; **Revised** 21 June, 2024;
Accepted 26 June, 2024
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plains the application of satellite technology to crop health assessments. Third, we discuss methods to use satellite technology for yield prediction and resource optimization in agriculture. Finally, this paper presents the current state and future prospects of satellite technologies in agriculture.

The intent of this review was to provide researchers, policymakers, and industry leaders in the agricultural sector with strategies and methods necessary to enhance agricultural productivity and ensure the sustainability of agriculture. The application of satellite technology in agriculture is expected to play a crucial role in the innovation and development of the agricultural industry.

2. Satellite Imaging and Remote Sensing Technologies

Satellite sensors with various spectral bands provide high-resolution images that enable detailed analysis of crop characteristics such as chlorophyll content, moisture levels, and canopy structure (Grody, 1976; Behrenfeld et al., 1997; Ma et al., 2017). Remote sensing platforms, including satellites and drones, acquire data over large areas, allowing the comprehensive monitoring of crop conditions. Remote-sensing technology using satellite images involves methods that utilize various sensors and imaging systems to observe and obtain information about the Earth's surface. The following are the main types of remote sensing technologies for satellite images. First, visible-light sensors measure and record light in the visible spectrum. They typically provide color information and are used to evaluate the crop growth status, soil characteristics, and surface features (Silvero et al., 2021; Feng et al., 2022). In addition, precise surface investigations using deep learning can be conducted based on this information (Korznikov et al., 2021). Second, near infrared (NIR) sensors measure light in the region between the visible and infrared spectra. Because chemicals such as chlorophyll in plants reflect light in the NIR range, these sensors are useful for assessing crop productivity, growth status, and health (Yang et al., 2012; Mohamed et al., 2020; Silvero et al., 2021). NIR sensors mounted on satellites facilitate the evaluation of large areas. Third, thermal infrared (TIR) sensors measure Earth's heat emissions to map surface temperatures. These sensors are used to evaluate soil moisture conditions, crop, and water stress (Sayão et al., 2018; Karthikeyan et al., 2020). Fourth, multispectral sensors measure light across multiple spectral bands. These sensors utilize various spectra, such as visible light, NIR, and TIR, to assess crop health, soil properties, and environmental conditions. Fifth, high-resolution optical sensors capture the Earth's surface at high resolution, enabling a detailed analysis of the terrain and objects. These sensors are used for crop monitoring, soil surveys, and terrain modeling and can also be employed for forest management (Lee et al., 2009; Lee et al., 2011; Kim et al., 2019; Park et al., 2020). Remote-sensing technologies are crucial in enhancing agricultural productivity and monitoring crop health and productivity.

3. Applications in Crop Health Assessment

Satellite data facilitates the detection of diseases, pests, and nutritional deficiencies in crops, enabling timely intervention and management strategies. Monitoring plant growth stages and identifying stress factors, such as water deficiency or temperature fluctuations, can also be achieved using satellite-based technologies. Remote sensing technology using satellite images has various applications in crop health assessment. Below are examples of these applications. Crop-stress detection technologies have been used to identify stress-inducing factors in areas where crops are cultivated (Ahmad et al., 2021). These factors include water deficiency, nutrient deficiency, and pest infestation. The stress status of crops can be evaluated by analyzing indicators such as color changes, growth inhibition, and morphological changes in crops through satellite images. Second, the early detection of diseases and pests is crucial for maintaining crop productivity (Yuan et al., 2017; Abd et al., 2020). Remote sensing technology can be used to survey entire crop fields to detect diseases or pests quickly. This enables the implementation of preventive measures and timely treatment of crop fields. Third, monitoring soil conditions is vital for crop health assessment because the condition of the soil is as important as the crops themselves. Remote-sensing technology has been used to evaluate soil moisture levels, pH, and cover (Peng et al., 2015; Cao et al., 2022). This helps to understand the soil conditions that affect crop growth and determine appropriate management methods. Fourth, the crop growth status can be assessed using satellite images (Huang et al., 2019; Karthikeyan et al., 2020). The growth status of crops can be tracked, and productivity can be predicted by analyzing indicators such as vegetation indices, biomass, and crop height. These examples demonstrate the significant role of remote sensing technology in improving crop health and productivity. Thus, agricultural productivity can increase, contributing to strengthening food security.

4. Yield Prediction and Resource Optimization

Sophisticated algorithms and models leverage satellite data to predict crop yields, aiding farmers in making informed planting, harvesting, and market planning decisions. Furthermore, satellite-based information can guide resource optimization efforts, including precision management and efficient fertilizer application, leading to improved efficiency and cost savings. Remote-sensing technology using satellite images is highly useful for yield prediction and resource optimization. Below are some key applications for these purposes. First, yield prediction can be achieved using satellite images to monitor crop field growth conditions and predict crop productivity (Schwalbert et al., 2020). By analyzing indicators, such as vegetation indices, biomass, and crop height, it is possible to predict both the quantity and quality of harvestable crops. A comprehensive evaluation of various factors affecting crop productivity was used to build yield prediction models. These models provide accurate predictions by considering the crop type, soil conditions, weather conditions, and crop management capabilities. Secondly, satellite data can aid in optimizing irrigation and fertilization (Veysi et al., 2017; Ihuoma et al., 2021). Data obtained from sensors mounted on satellites measure the soil moisture levels and nutrient concentrations in crop fields, which are then used to optimize yields. Based on the yield prediction results, irrigation and fertilizer supply can be adjusted to maximize the efficiency of resource use. The precise provision of water and nutrients crops required by crops enhances productivity while minimizing resource consumption. Third, harvest timing can be optimized by assessing crop growth status and productivity predictions (Becker et al., 2021). By using prediction models to determine the optimal harvest time, farmers can adjust their harvesting schedules to maximize yield. This ensures that crops are harvested at their peak, enhancing overall productivity. Fourth, remote-sensing technology aids resource allocation and management planning (Jahn, 2001; Fu et al., 2020). It is used to allocate resources efficiently and optimize management plans by considering the spatial distribution of crop fields. This optimization of the resource supply to specific areas of the crop field enhances productivity and prevents inefficient resource use. These methods contribute significantly to enhancing agricultural productivity while simultaneously optimizing resource use, facilitating sustainable agricultural management.

5. Challenges and Future Directions

Despite these benefits, satellite technology in agriculture faces challenges, such as data accessibility, processing limitations, and the need for improved accuracy and reliability. Addressing these challenges requires ongoing research and innovation, including integrating satellite technology, data analysis, and ground-based observations. Although remote sensing technology using satellite images is highly beneficial for agriculture, several challenges and future directions remain. The key considerations are as follows.

First, the resolution and accuracy must be improved. Although the resolution and accuracy of current satellite images are continually improving, higher resolution and accuracy are required in some cases. Detailed information of small areas within crop fields requires high-resolution imaging. Therefore, it is essential to enhance the performance of satellite sensors to measure the various characteristics of crop fields more accurately. For a similar case, using unmanned aerial vehicles (UAV), the resolution of images was very important. Higher resolution images yielded more data and resulted in more accurate predictions (Ku et al., 2023). While a definitive answer is not appropriate here, the image resolution should be as high as possible without overburdening communication systems. With technological advancements, it is anticipated that higher resolution images will be increasingly utilized.

Second, an efficient data processing and analysis system is required. The effective processing and analysis of large volumes of satellite image data remain challenging. In agriculture, data processing and analysis systems must be enhanced to monitor crop conditions in real-time and facilitate rapid decision-making. Hence, improving data processing and analysis technologies is crucial for future research.

Third, fusion technology and multisensor integration are required. Using satellite images in agriculture requires the fusion of data from other sensors and sources. This integration provides richer information and more accurate insights into crop health assessments and productivity predictions. Thus, developing multisensor integration and fusion technologies is a future direction for satellite imagery in agriculture.

Fourth, farmer education and technology adoption are necessary. Farmer education and technology adoption are crucial for effectively applying remote sensing technology using satellite images in agriculture. Provide educational resources and training to help farmers understand and utilize satellite imaging technologies is essential. For example, Saefarm, a startup company in korea founded in 2022, has analyzed images from over 220 satellites both domestically and internationally to secure various agricultural information, such as crop growth conditions, yield predictions, and optimal crop recommendations. Currently, they analyze various agricultural products, including powder rice, garlic, and radish, over an area of 96 hectares and for 1,048 farms in Korea, providing related information to farmers and the government daily. This serves as a prime example of the importance of education and technology adoption in helping farmers effectively utilize satellite imagery.

Information security and privacy: Satellite image data include personal and sensitive information, making information security and privacy important considerations. Strengthen data security and privacy policies for satellite image data in agriculture is essential.

Addressing these challenges will further advance remote-sensing technology using satellite images, thereby enabling more effective utilization in various fields. This process is expected to enhance agricultural productivity and promote sustainable development.

6. Conclusion

Satellite technology has revolutionized crop monitoring and management, offering unprecedented capabilities for precision agriculture and sustainable food production. As technology continues to advance, integrating satellite data with advanced analytics holds immense potential for optimizing agricultural practices and addressing global food security challenges. This mini-review provides a glimpse into the transformative role of satellite technology in agriculture and highlights its importance in shaping the future of crop monitoring and management.

Acknowledgements

This work was supported by the 2024 education, research and student guidance grant funded by Jeju National University.

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