An Integrated Approach for Agricultural Monitoring based on Internet of Things (IoT), Remote Sensing and Deep Learning

ABSTRACT:

The agriculture sector holds a dominant position in Pakistan's economy, accounting for 37.4% of employment generation and playing a key role in ensuring food security. Despite the nation's GDP heavily relying on agriculture, the current method of manually monitoring crops is labor-intensive and inefficient, resulting in quality and production losses. In contrast, developed countries have successfully adopted precision agriculture (PA) as a widely used technique to optimize resource utilization and enhance crop yield. To address this disparity, this research aims to explore the potential of advanced technologies like remote sensing with the Internet of Things (IoT), along with machine and deep learning for developing countries like Pakistan. By utilizing these cutting-edge tools, this study significantly contributes to the transformation of agricultural practices. The pivotal impact of this research unfolds through its key contributions: (i) the introduction of multi-modal data integration for detailed crop health monitoring, (ii) employing machine and deep learning techniques for effective disease detection and its severity level classification, (iii) insightful analysis of fertilizer impact on crops through remote sensing, (iv) employing regression techniques for accurate yield prediction using multisource data.

Traditionally, crop health analysis relies on separate utilization of drone imagery and IoT sensor data. This research introduces a novel multi-modal approach synergizing these technologies with machine learning. This innovative integration produces comprehensive crop health maps, wherein a multi-layer neural network (NN) achieves an accuracy of 98.4%. This accuracy is attributed to the network's ability to harness real-time insights from IoT sensors and the detailed information provided by drone-captured multispectral imagery. Furthermore, crop disease detection, especially concerning devastating diseases like wheat rust, remains a pivotal concern in agriculture. This research endeavors a unified framework by utilizing Grey Level Co-occurrence Matrix (GLCM) and Local Binary Patterns (LBP) texture features. This data is subsequently processed through advanced machine learning techniques, where CatBoost outperformed with 92.30% accuracy. Delving deeper into rust disease severity levels, the study harnesses deep learning techniques, with the ResNet-50 improving the classification performance up to 96%. Moreover, the research investigates the efficacy of integrated nutrient management (INM) practices on wheat yield. By analyzing NDVI maps and crop height throughout the growth cycle, the INM approach is shown to significantly enhance wheat productivity, leading to a notable increase in crop grain yield. Furthermore, crop yield prediction is crucial for informed farming decisions and resource optimization. Several research studies exist on this topic, only a few have explored the tangible potential of using multi-source data and considering the optimal time for yield prediction. Toward this end, this study utilizes multi-source data emphasizing the optimal timing for yield prediction by leveraging drone multispectral data and agronomic traits. Notably, the Least Absolute Shrinkage and Selection Operator (LASSO) outperformed, achieving outstanding performance with a coefficient of determination (R^2) of 0.93 and a mean absolute error (MAE) of 21.72 g/m^2.

In its entirety, incorporating remote sensing with IoT, along with machine and deep learning technologies reshapes agriculture. This synergy enables data-driven decisions, enhances productivity, reduces disease risks, and optimizes resource allocation, offering sustainable solutions for food security.

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