Development and Multi-Source Validation of a Smart Weather Monitoring System for Mountainous Rice Applications

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Abstract

Precise environmental monitoring has become increasingly important under Climate Change, which has intensified temperature variability and altered local weather patterns, particularly in mountainous agricultural regions. These changes directly affect crop growth, yield stability, and the quality of food products such as rice. However, conventional forecast systems often fail to capture field-level microclimatic variability, limiting their effectiveness for precision agriculture applications.

This study presents the design and evaluation of a low-cost, IoT-based smart weather monitoring system. Sensor measurements were compared with ERA5 reanalysis data and forecast data across two observation periods. After applying data quality control to remove incomplete records, ERA5 showed moderate agreement with sensor observations ($r = 0.69$ for minimum temperature and $r = 0.44$ for maximum temperature). In contrast, forecast data demonstrated weak and inconsistent performance, particularly for minimum temperature ($r \approx -0.09$, RMSE = 4.81°C). Mean temperature exhibited improved reliability ($r = 0.68$, RMSE = 1.32°C), suggesting its suitability for validation purposes.

The results indicate that large-scale datasets such as ERA5 can effectively represent general climatic trends but are limited in capturing localized microclimatic variations. Forecast data may be less reliable in complex terrains such as mountainous agricultural landscapes. The proposed system enables real-time, field-level environmental monitoring, supporting improved decision-making in rice cultivation, enhancing yield management, and ensuring the quality and consistency of rice-based products under changing climate conditions.

Keyword: Weather Station, ERA5, IoT, Microclimate, Rice cultivation, RMSE