



Agrometeorology for Precision Agriculture and Resource Optimization

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Abstract

Agrometeorology, the interdisciplinary field linking meteorological science and agriculture, is essential for advancing precision agriculture a management strategy that integrates digital technologies for site-specific field management. Harnessing agrometeorological insights allows for optimized use of water, fertilizers, pesticides, and other agronomic inputs, ultimately increasing resource efficiency and environmental sustainability. Agrometeorology enhances precision agriculture by guiding the strategic implementation of advanced practices such as weather-informed irrigation scheduling, targeted nutrient application, and data-driven pest and disease management. Integrating high-resolution meteorological data and digital farming technologies empowers farms to improve productivity and operational efficiency, while simultaneously building resilience to climate variability and resource constraints.

Keywords: Agrometeorology, Precision, Sustainability, Optimization, Resilience

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Introduction

Global agriculture faces unprecedented challenges: climate change, resource scarcity, environmental degradation, and a growing human population. By 2050, the world's population is projected to reach 9.6 billion, placing substantial pressure on food systems (UN Report, 2024). Traditional farming systems, reliant on uniform input applications and historical experience are increasingly untenable in the face of unpredictable weather and fluctuating resource availability. Precision agriculture represents a paradigm shift, leveraging technology and data-driven decision-making for efficient crop management and sustainability. Agrometeorology, with its expertise in climate, weather, and soil-plant-atmosphere interactions, forms the backbone of this transformation by providing real-time, field-specific guidance on where, when, and how much to intervene.

The Foundation of precision agriculture

Precision agriculture (PA) employs spatially and temporally resolved data from sensors, weather stations, satellites, and drones to monitor crop status, soil moisture, and microclimate conditions (Mamabolo et al., 2025). This enables farmers to respond proactively to intra- and inter-field variability. Machine learning and

artificial intelligence (AI) models further enhance decision accuracy, forecasting yield, water stress, and pest risk with high resolution.

Optimizing resource use with Agrometeorological data

Agrometeorological data are indispensable for fine-tuning irrigation, fertilization and crop protection strategies:

Irrigation Scheduling: Estimates of temperature, humidity, solar radiation, and wind drive crop evapotranspiration (ET) models, enabling smart irrigation scheduling that prevents both under- and over-watering. Systems integrating soil moisture sensors, weather forecasting, and automated controls minimize water waste and support drought resilience.

Nutrient management: Weather-informed fertilizer applications align with optimal root uptake periods while reducing runoff loss and environmental impact. This targeted approach enhances nutrient use efficiency and curbs pollution.

Pest and disease forecasting: Agrometeorological indices predict periods of heightened pest and disease risk, facilitating precise, timely interventions. Data-driven pesticide recommendations help reduce

chemical inputs and resistance build-up (Lee & Zhang, 2024).

Integration with digital and remote technologies

Modern agrometeorology for precision agriculture relies on the seamless integration of multiple technologies:

- **IoT Sensors and remote sensing:** Networks of in-field sensors and drone or satellite imagery deliver real-time data on temperature, humidity, rainfall, and crop condition. These high-resolution data streams feed AI models to produce actionable agro-advisories, from frost warnings to yield forecasts (Mangaraj et al., 2025).
- **Decision Support Systems (DSS):** DSS platforms harness meteorological data, farm histories, and predictive models to deliver field-by-field recommendations, helping farmers maximize efficiency and minimize risks (Saha et al., 2025).

Environmental and economic benefits

Efficient resource use, empowered by agrometeorology, leads to:

- **Lower input costs:** Precise allocation of water, fertilizer, and chemicals reduces waste and saves money, increasing farm profitability.
- **Sustainability:** Optimized input use leads to less runoff, pollution, and greenhouse gas emissions, making farming both productive and environmentally friendly.
- **Climate resilience:** Meteorological decision-support enables growers to adapt quickly to droughts, heatwaves, and storms, reducing crop losses and stabilizing yields (Farmonaut, 2025).

Policy, extension, and future directions

For agrometeorology-driven precision agriculture to reach its full potential, supportive policy, robust extension services, and ongoing research are crucial:

- **Policy alignment:** National and regional policies recognizing the importance of meteorological data integration can provide incentives for technology adoption and resource conservation practices (Farmonaut, 2025).
- **Extension services:** Translating complex weather data and analytic outputs into practical advisories empowers farmers and bridges the technology-access gap. Mobile advisory platforms and knowledge hubs are vital for smallholder inclusion.
- **Future research:** Further advances in sensor technology, edge computing, machine learning, and interoperability will expand the scope and impact of agrometeorology for precision agriculture (Mamabolo et al., 2025).

Conclusion

Agrometeorology is the scientific cornerstone of precision agriculture, empowering farmers to use resources wisely while maintaining productivity and resilience. Through the continuous integration of weather, soil, and crop data analyzed and acted upon with real-time digital tools—agriculture can be transformed for a resource-constrained, climate-challenged future. Prioritizing research, policy support, and technological dissemination will ensure that agrometeorology fully delivers on its promise of sustainable, profitable, and climate-smart agriculture.

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