

COMPUTER MODELS IN AGRICULTURAL METEOROLOGY: A MODERN TOOL FOR CLIMATE-SMART FARMING

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ABSTRACT

Agricultural production is strongly influenced by weather and climate variables, including temperature, rainfall, humidity, solar radiation, wind speed, and soil moisture. Agricultural meteorology employs computer models to translate these observations into actionable information for crop management and decision-making. Process-based models such as DSSAT, APSIM, WOFOST, and CERES simulate crop growth and yield. Recent advances in artificial intelligence, machine learning, remote sensing, and big data have enhanced predictive capabilities. Integrating crop-growth processes with data-driven approaches can strengthen climate resilience, optimize resource use, and improve agricultural sustainability.

KEYWORDS: Agricultural meteorology, APSIM, Climate change, Computer models, Crop simulation, Decision support system, Machine learning, Weather forecasting

INTRODUCTION

Agricultural meteorology is the science of understanding how weather and climate affect agriculture. Farmers traditionally depend on their experience to make decisions about sowing, irrigation, fertilization and harvesting. However, increasing weather variability, droughts, heat waves, intense rainfall and changing growing seasons make farm decisions more difficult. Computer models provide a scientific way to understand these complex interactions and explore different management options before they are implemented in the field.

A computer model is essentially a mathematical representation of a real agricultural system. It uses information such as daily temperature, rainfall, solar radiation, soil characteristics, crop variety, sowing date, irrigation and fertilizer application to simulate crop development and estimate outcomes. Modern crop models can therefore act as a “virtual field” in which different weather and management scenarios can be tested.

MAJOR TYPES OF COMPUTER MODELS

1. *Statistical and empirical models:* These models establish relationships between weather variables and agricultural outcomes. For example, historical rainfall and temperature data can be related to crop yield. They are relatively simple and useful for yield forecasting, but their performance may decline when weather conditions are substantially different from the historical data.
2. *Process-based crop models:* These models represent biological and physiological processes such as photosynthesis, respiration, phenological development, biomass accumulation and water use. Well-known examples include DSSAT, APSIM, WOFOST and CERES. They can evaluate the effects of sowing date, irrigation, nitrogen management, temperature and future climate scenarios. Recent research continues to demonstrate the value of these models for crop management and climate-resilient agriculture.
3. *Weather and agro-meteorological models:* Weather prediction models provide forecasts of temperature, rainfall, wind, humidity and other variables. When linked with agricultural models, these forecasts can generate practical advisories such as whether irrigation should be postponed, whether spraying conditions are suitable, or whether heavy rainfall may affect harvesting.
4. *Artificial intelligence and machine-learning models:* Machine learning techniques such as Random Forest, XGBoost, artificial neural networks and deep learning can analyse large datasets from weather stations, satellites, sensors and crop observations. They are increasingly being used for yield prediction, drought assessment, evapotranspiration estimation and crop stress detection. However, purely data-driven models may have difficulty when they encounter environmental conditions that were not represented in their training data.
5. *Hybrid models:* One of the most promising developments is the combination of process-based crop models with artificial intelligence. Such models attempt to combine the biological understanding and interpretability of traditional crop models with the predictive ability of machine learning. Recent research on next-generation crop models identifies integration with machine learning, sensors, standardized databases and remote sensing as important directions for future agricultural modelling.

APPLICATIONS IN AGRICULTURAL METEOROLOGY

Computer models have numerous applications in agriculture. They can estimate crop yield before harvest, identify optimum sowing windows and assess the effects of delayed sowing. They can also estimate crop water requirements and support irrigation scheduling. By combining weather forecasts with crop

information, models can provide early warnings for drought, heat stress, frost, heavy rainfall and other extreme events.

Models are also useful for climate-change impact assessment. Researchers can simulate crop performance under future temperature and rainfall scenarios and compare adaptation measures such as changing sowing dates, selecting heat-tolerant varieties, modifying irrigation or improving soil management.

Another important application is agro-advisory services. Model outputs can be converted into simple recommendations for farmers through mobile applications, websites and extension services. In India, recent agro-meteorological programmes have emphasized the development of weather-based decision systems, climate adaptation tools and farmer-oriented technologies.

CHALLENGES AND FUTURE PROSPECTS

Despite their advantages, computer models are not perfect. Their accuracy depends on the quality of weather, soil and crop data and on appropriate calibration and validation. Different models may produce different results because they represent agricultural processes differently. Recent research has highlighted the importance of quantifying uncertainty rather than relying only on a single model prediction.

Future agricultural meteorology will increasingly use real-time weather observations, automatic weather stations, Internet of Things sensors, satellite imagery, drones, artificial intelligence and cloud computing. Multi-model and hybrid approaches are likely to provide more reliable predictions than relying on one modelling technique. Greater integration of farmer knowledge with model-based information will also be important for developing practical and locally relevant advisories.

CONCLUSION

Computer models have become an important component of modern agricultural meteorology. They provide a scientific framework for linking weather, soil, crop and management factors and converting complex data into useful agricultural information. From conventional crop simulation models to artificial intelligence and hybrid modelling systems, technological development is making agricultural predictions increasingly detailed and timely. However, successful application requires high-quality data, proper calibration, validation and communication of uncertainty. The future lies in integrating process-based models, machine learning, remote sensing and real-time weather information into farmer-friendly decision-support systems. Such computer-based approaches can contribute significantly to climate-smart agriculture, efficient use of water and fertilizers, reduction of weather-related risks, and sustainable food production.

SUGGESTED READINGS

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