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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1035641

Project Title

Partnership: Precision Irrigation Management in Corn: Integrating Sensors, Crop Models, and Artificial Intelligence

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** ACTIVE
Funding Source NIFA Non Formula	**Grant Year** 2027
Grant No. 2027-67021-47738	**Cumulative Award Amt.** $799,998.00
Proposal No. 2025-10181	**Multistate No.** (N/A)
Project Start Date Nov 01, 2026	**Project End Date** Oct 31, 2029
Program Code [A1551] Engineering for for Precision Water and Crop Management	

Project Director

Ale, S.

Recipient Organization

TEXAS A&M AGRILIFE RESEARCH

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Performing Department

(N/A)

Non Technical Summary

Corn producers in the Northern High Plains of Texas face growing challenges from rapidly declining groundwater levels in the Ogallala Aquifer and increasing severity and frequency of droughts. As water supplies become more limited, producers need better ways to decide when to irrigate and how much water to apply. This three-year project will integrate data from wearable plant sensors, soil and canopy sensors, drone images, crop models, and artificial intelligence to develop and test better irrigation decision tools for corn.Field experiments at Bushland, TX, will compare corn grown under three irrigation levels. Novel wearable plant sensors will be developed and refined to continuously monitor two key drought-related phytohormones, abscisic acid and salicylic acid, for early detection of crop water stress. These sensors will be field-tested alongside canopy temperature, sap flow, and soil moisture sensors under full and deficit irrigation. UAV-based thermal and multispectral imagery will be collected to map spatial variability in crop growth and development. The DSSAT CERES-Maize model will be calibrated using field measurements to suggest

efficient irrigation strategies that use water more efficiently. Residual learning will be used to reduce DSSAT model prediction bias, while explainable AI will help identify factors associated with prediction errors. An AI-enhanced digital twin will be developed by integrating real-time sensor data, UAV imagery, and DSSAT model outputs to forecast plant water stress and recommend irrigation actions through an interactive decision-support dashboard. The project intends to provide a research foundation for practical irrigation tools that support corn production and groundwater conservation in the Northern High Plains of Texas.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	20%
Applied	70%
Developmental	10%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
111	1510	1020	10%
111	1510	2050	10%
205	1510	2050	20%
205	1510	1020	20%
402	1510	2020	40%

Knowledge Area

[111] Conservation and Efficient Use of Water

[205] Plant Management Systems

[402] Engineering Systems and Equipment

Subject Of Investigation

[1510] Corn (for sweetcorn use 1480)

Field Of Science

[1020] Physiology

[2050] Hydrology

[2020] Engineering

Keywords

water use efficiency, Precision irrigation, DSSAT, wearable sensors, digital twin

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Goals / Objectives

The overall goal of this project is to enhance the water use efficiency (WUE) of corn in the Northern High Plains region of Texas by integrating plant water stress sensors, crop models, and machine learning (ML)-based approaches. Specific objectives are to:Objective 1. Develop and refine in-situ, wearable plant water stress sensors that enable early detection and continuous monitoring of water stress and real-time measurement of key phytohormones [abscisic acid (ABA) and salicylic acid (SA)].Objective 2. Compare the performance of soil water, sap flow, canopy temperature, and wearable hormone sensors in irrigation management in a field experiment.Objective 3. Develop a DSSAT-ML framework that integrates residual errors and phytohormone data to improve DSSAT predictions and evaluate water-efficient irrigation strategies.Objective 4. Develop an artificial intelligence (AI)-enhanced digital twin framework for real-time prediction of plant water stress and irrigation optimization by fusing multimodal sensor data, DSSAT simulations, and unmanned aerial vehicle (UAV) imagery.

Project Methods

Objective 1. Wearable electrochemical sensors will be developed and refined for in-situ measurement of the drought related phytohormones, abscisic acid (ABA) and salicylic acid (SA). The sensors will be integrated with a data acquisition system programmed to record measurements every five minutes. Approximately 10 sensors will undergo initial field testing for one month in Year 1, and the findings will guide refinements in the design. In Years 2 and 3, approximately 10 sensors per irrigation treatment, or 30 in total, will be evaluated for two to three months after corn stems reach a suitable size for installation. Sensor measurements will be compared with laboratory measurements using liquid chromatography. Evaluation will include sensitivity, selectivity, detection limits, repeatability, recovery, drift and operating lifetime. Stress-detection timing will be compared with conventional sensors to determine whether hormone measurements provide earlier, actionable indications of water stress.Objective 2. A field experiment will be conducted at Bushland, TX, under a center-pivot irrigation system. Treatments will include 100%, 75% and 50% of crop evapotranspiration replacement with three replications. Target seeding rates will be 32,000 seeds per acre for the 100% and 75% treatments and 24,000 seeds per acre for the 50% treatment. Soil-water sensors, sap-flow sensors, canopy-temperature sensors and wearable hormone sensors will be deployed and evaluated for detecting crop water stress and guiding irrigation decisions. Multispectral and thermal unmanned aerial vehicle (UAV) imagery will be collected for developing vegetation indices. These indices and canopy temperature measurements will be used to assess crop conditions and spatial differences in water stress. The combined sensor and UAV data and field measurements will be used to compare crop yield and crop water productivity under different irrigation management treatments implemented in the field experiment and to provide guidance on irrigation management decisions. Objective 3. The DSSAT CERES-Maize model will be calibrated and evaluated using measured data from the field experiment. Conventional calibration will be compared with a physiology-informed approach that aligns measured abscisic acid (ABA) and salicylic acid (SA) responses with the model's simulated water-stress factors, SWFAC and TURFAC. Machine-learning (ML) models will predict residual errors, defined as observed yield minus DSSAT-predicted yield, using weather, soil, management data and relevant DSSAT outputs. Candidate methods will include elastic net, random forest, XGBoost, support vector regression and a small multilayer perceptron. ML model performance will be assessed through cross-validation and held-out testing. SHapley Additive exPlanations (SHAP) will identify factors associated with recurring prediction errors and guide targeted model updates. Predicted residuals will be added to DSSAT yield predictions to produce hybrid DSSAT-ML predictions. The evaluated crop model will then be used to run long-term simulations with different scenarios, and to suggest efficient irrigation strategies for corn production in the Northern High Plains.Objective 4. An AI-enhanced digital twin will be developed by integrating field sensor measurements, UAV imagery, weather information and DSSAT simulations into a continuously updating digital representation of crop conditions. Sensor streams will be synchronized at 15-minute intervals. Automated quality assurance and quality control procedures will be used to detect outliers, fill data gaps and track sensor drift. Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRU) models will generate short-term forecasts and will be compared with baseline methods such as autoregressive integrated moving average (ARIMA). Predictive performance of the digital twin will be assessed using blocked time-series cross-validation and spatial holdouts. Reinforcement

learning will be used to evaluate irrigation timing and amounts in a simulation environment. Bayesian methods will quantify uncertainty. These methods will be combined with short-term forecasting in the final AI pipeline for irrigation optimization. Irrigation recommendations will be compared with ET-based schedules, and sub-field prescriptions will be evaluated against uniform irrigation strips. A web-based dashboard will be developed to display crop conditions, stress maps, three- to five-day forecasts, irrigation alerts and scenario comparisons. The digital twin will be evaluated for water savings, yield stability and irrigation efficiency. Dashboard testing will be performed to assess interpretability and responsiveness.