Awards issued prior to January 20, 2025, were funded under previous Administrations and may not reflect the priorities and policies of the current Administration.

United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1034542

Project Title

HRFarm: A Sustainable, Unmanned, and AI-driven Cyber-Physical System to Monitor and Analyze High-Resolution Crop-Environment Interactions for Precision Agriculture

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** ACTIVE
Funding Source NIFA Non Formula	**Grant Year** 2026
Grant No. 2026-67022-45762	**Cumulative Award Amt.** $586,000.00
Proposal No. 2024-12663	**Multistate No.** (N/A)
Project Start Date Feb 15, 2026	**Project End Date** Feb 14, 2030
Program Code [A1551] Engineering for for Precision Water and Crop Management	

Project Director

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Recipient Organization

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Performing Department

Department of Electrical and Computer Engineering

Non Technical Summary

Farmers increasingly face challenges from changing weather conditions, rising production costs, and the need to use water, fertilizers, and pesticides more efficiently while maintaining crop yields. However, many farms lack affordable tools to continuously monitor crop and soil conditions, making it difficult to detect crop stress, disease, or field problems early enough for effective action. Improving farm monitoring systems is important not only for farmers' profitability, but also for supporting stable food production and strong rural economies.This project will develop and test a low-cost, automated farm monitoring system called HRFarm that uses smart sensors, wireless communication, and artificial intelligence to continuously observe crop, soil, and field conditions in agricultural fields. The system will be tested in real farm environments, and the collected information will be analyzed to help farmers better understand crop health, manage water and nutrients more efficiently, and respond earlier to disease or stress risks. By providing

reliable, easy-to-use monitoring tools and training students and agricultural professionals in modern farming technologies, the project aims to improve farm productivity, reduce unnecessary input use, strengthen farm management practices, and support long-term agricultural productivity benefiting farmers, rural communities, and consumers.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	15%
Applied	45%
Developmental	40%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
404	7210	2080	20%
205	0120	2020	80%

Knowledge Area

[404] Instrumentation and Control Systems

[205] Plant Management Systems

Subject Of Investigation

[7210] Remote sensing equipment and technology

[0120] Land

Field Of Science

[2080] Mathematics and computer sciences

[2020] Engineering

Keywords

Blueberry, Precision Agriculture, Water Management, Machine Learning, Crop Health

Goals / Objectives

Major Goal:The major goal of this project is to develop and deploy HRFarm, an unmanned and AI-driven cyber-physical system that enables continuous, high-resolution monitoring and analysis of crop, pest, and field conditions. The system aims to support precision agriculture practices, improve water, nutrient, and pesticide use efficiency, and strengthen crop production reliability under changing weather conditions while reducing operational burden on growers. Objectives:Design and deploy a scalable, low-cost cyber-physical sensing infrastructure capable of continuously collecting high-resolution crop and field-condition data across agricultural fields.Develop reliable wireless networking,

forecasting-based energy management, and edge computing solutions to enable continuous, unmanned operation of sensing and data-processing systems under real agricultural field conditions.Conduct multi-year field validation studies to link HRFarm sensor measurements with laboratory and in-field observations of soil properties, crop growth, physiology, disease infection, weed pressure, and yield outcomes.Develop AI-driven data analytics and predictive models to quantify crop-pest-environment interactions and provide actionable decision support tools for crop management and precision agriculture.Train graduate and undergraduate students in agricultural cyber-physical systems, AI-driven sensing, and precision agriculture technologies to strengthen workforce development supporting modern agricultural systems.

Project Methods

This project develops and evaluates HRFarm, an unmanned and AI-driven cyber-physical system for monitoring crop, pest, soil, and field conditions in agricultural fields. The project integrates sensing technologies, wireless communication, edge computing, and artificial intelligence to enable continuous monitoring and analysis supporting precision agriculture.Research and System Development MethodsThe project will design and deploy a multi-modal sensing network consisting of aboveground and underground sensors, wireless communication infrastructure, and edge-computing devices powered by photovoltaic energy systems. Sensors will monitor soil moisture, temperature, field conditions, crop canopy characteristics, and disease and weed indicators. Edge computing devices will perform local data preprocessing, cross-verification of sensor signals, and data compression to ensure reliability and reduce transmission cost.Forecast-based energy management will be developed to maintain continuous operation using solar power, while fault-tolerant networking and redundancy-aware data processing methods will ensure robust data collection in real field conditions. Field deployments will occur in commercial agricultural fields to validate system performance.Data Analysis and ModelingCollected sensing data will be integrated with laboratory and field measurements of soil properties, crop physiology, disease infection, weed pressure, and yield. Statistical and machine learning methods, including causal modeling and predictive analytics, will be used to quantify crop-pest-field interactions and develop predictive models for crop stress, disease risk, and productivity. Models will be validated through multi-season field data comparisons.Efforts to Deliver Knowledge and TechnologyProject results will be disseminated through classroom and laboratory instruction, student research training, conference presentations, publications, and outreach engagement with growers and extension personnel. Field demonstrations and collaboration with extension networks will support translation of research findings into practical agricultural management guidance. Graduate and undergraduate students will participate in system deployment, data collection, and analysis, providing experiential learning opportunities in agricultural sensing and AI technologies.Evaluation and Impact MeasurementProject success will be evaluated using measurable indicators including system deployment reliability, data collection continuity, accuracy of predictive models, number of students trained, publications produced, and outreach activities conducted. Evaluation will also consider adoption potential of developed technologies and feedback from growers and extension stakeholders regarding usefulness of monitoring and decision-support tools.Quantitative evaluation will include comparisons between sensor measurements and field observations, improvements in monitoring accuracy, and demonstration of predictive model performance across growing seasons. These metrics will be used to guide system improvement and measure project impact on research and agricultural management practices.