United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1022122

Project Title

CPS: Medium: Collaborative Research: Field-scale, single plant-resolution agricultural management using coupled molecular and macro sensing and multi-scale data fusion and modeling

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2020
Grant No. 2020-67021-31528	**Cumulative Award Amt.** $786,362.00
Proposal No. 2020-01463	**Multistate No.** (N/A)
Project Start Date Jun 01, 2020	**Project End Date** May 31, 2025
Program Code [A7302] Cyber-Physical Systems	

Project Director

Dong, L.

Recipient Organization

IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

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ELECTRICAL AND COMPUTER ENGINEERING - ENG

Non Technical Summary

Water and nitrogen represent two of the most expensive inputs to agricultural systems, and two of the critical constraints on overall agricultural productivity. Today, farmers generally over apply nitrogen fertilizer, because the potential cost of over application is less than the potential cost of achieving suboptimal yields. Similarly, in farm settings water is often over applied, particularly when studies are conducted at high resolution within individual center-pivot fields. We willdesignand validatean integrated cyber-physical system to collect and integrate data from remote sensing and low-cost field deployed wearable sensors and use machine learningand mathematical modeling to guide precision water and nutrient interventions in farmer's fields. This would mean that agricultural productivity can be sustained or increased while reducing overall nitrogen fertilizer and irrigation applications. Among the many beneficial effects to society as a whole would be 1) a decrease the environmental impact of agriculture; 2) decreased competition for scarce water supplies between agriculture and growing urban centers; and 3) increased farmer profitability, improving the economic viability of rural economies.The CPS will enable fusion of a large volume of spatio-temporally distributed multi-modal information to create a data-driven decision support platform that provides actionable information on optimal agricultural managementstrategies.The team will continue to leverage and develop extensive outreach and educational activities to train the next generation of scientists, through many existing STEM programs in Iowa State University and University of Nebraska-Lincoln.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	34%
Applied	33%
Developmental	33%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
404	0199	2020	50%
111	0199	1081	25%
102	0199	2080	25%

Knowledge Area

[404] Instrumentation and Control Systems

[111] Conservation and Efficient Use of Water

[102] Soil, Plant, Water, Nutrient Relationships

Subject Of Investigation

[0199] Soil and land, general

Field Of Science

[2020] Engineering

[1081] Breeding

[2080] Mathematics and computer sciences

Keywords

Agricultural Management, Modeling, Machine Learning, Wearable Sensors

Goals / Objectives

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This proposal is to develop and validate a cyber-physical system (CPS) to address agricultural grand challenges in improving crop water and nitrogen input use, through the seamless integration of low-cost wearable field sensors, remote sensing, control systems, analytic engines, decision-making algorithms, and testbeds. The ultimate goal is to improve agricultural management for crop production, environmental quality, and agricultural systems sustainability. The proposed CPS will not only allow real-time monitoring of crop nitrogen use efficiency and water use efficiency across scales ranging from molecular to individual-plant to whole-fields, but also bridge these scales by developing new data analytics approaches for extracting actionable information to deliver context-aware decision making of crop fertilization and irrigation scheduling.

Project Methods

The methods are describe in the following:(1) We will optimize the nitrogen and water sensor designs to make them more rugged, robust, and inexpensive for field deployment. This will be achieved through improving signal-to-noise ratio and reducingundesired measurement artifacts with proper electromagnetic shield and filter design, and introducing asleep mode with a rugged deployment architecture. To enable vapor pressure deficit measurement, we will combine a temperature sensing unit and arelative humidity sensing unit on a flexible substrate. For water potential measurement, we will reduce temperature-induced reading errors by balancing stress changes on asilicon substrate. These field sensors will use rechargeable batteries powered by solar panels. The sensors, data loggers, and solar panels will be installed in proper locations without affecting agricultural operations.(2)We will build a framwork to fuse multi-modal data and produce actionable/control feedback.Our approach to fuse multi-sensors data using calibrated crop modeling and data-fusion strategies. We will use the calibrated cropping systems modelto create a 'digital twin' of the field. The calibration will include initial nitrate distribution, and soil type and topology. We will integrate all the sensors, algorithms, and networks together to form the CPS for field-scale validation fordecision-making in agricultural water and fertilizer management to explain and predict plant-soil dynamics.(3) We will perform ground truth procedures that arerequired to bridge old and new methods while measuring accuracy. We will verify sensors with conventional measurements and cropping systems model outputs. As new sensors provide different high-resolution data streams, models can help to verify observed patterns and the new high-resolution sensor data can improve the models. We will conduct simulated head to head trials using existing data collected by the research team and mined from the literature to assess how accurately the CPS system and human experts can predict the impact of specific agricultural interventions on yield, WUE, and NUE. (4) We will design and implement innovative broader impacts activities. First, we will conduct "on-farm" extension education during established annual "Field Days", with a focus on hands-on work with sensors and subsequent use of computer simulation decision support systems to understand how genetics, environment and management interact to affect outcomes. Second, We will train STEM workforce through three NSF Research Traineeship and other STEM programs. We will work with three agriculture and plant sciences related NSF NRT educational programs at Iowa State and University of Nebraska to transfer the research process and findings to the next generation of agricultural professionals and leaders. These programs will be extended through this project. We will work with them to recruit a diverse STEM workforce to advance agriculture, and to train students to integrate engineering and data science. Last, we will broaden the participation of Underrepresented and Minority Students through through the existing University Honors Program and the Program for Women in Science and Engineering.