**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 1023249

## Project Title

Artificial Intelligence For Water, Nutrient, Salinity, And Pest Management In The Western U.S.

## Project Details

| | |
|---|---|
| **Sponsoring Institution**<br>National Institute of Food and Agriculture | **Project Status**<br>ACTIVE |
| **Funding Source**<br>NIFA Non Formula | **Grant Year**<br>2020 |
| **Grant No.**<br>2020-69012-31914 | **Cumulative Award Amt.**<br>$10,000,000.00 |
| **Proposal No.**<br>2019-08301 | **Multistate No.**<br>(N/A) |
| **Project Start Date**<br>Sep 01, 2020 | **Project End Date**<br>Aug 31, 2027 |
| **Program Code**<br>[A9201] Strengthening Agricultural Systems | |

## Project Director

Scudiero, E.

## Recipient Organization

REGENTS OF THE UNIVERSITY OF CALIFORNIA AT RIVERSIDE

200 UNIVERSTY OFC BUILDING

RIVERSIDE, CALIFORNIA 92521

## Performing Department

(N/A)

## Non Technical Summary

Vital to local rural communities and the national economy, agriculture in the western U.S. faces challenges including degradation of natural resources, climate variability, and pest outbreaks. Artificial Intelligence (AI) and Digital Agriculture (DA), the transdisciplinary application of high-performance computing and hyperdimensional data, can improve farming resilience. Short- and medium-term, this project applies DA to optimize current practices, maximizing efficiency, and minimizing waste. Long-term, the project develops a foundation of tools and knowledge for a shift to highly-automated mechanized systems for irrigation, nutrient, salinity, and pest management. Applied research supporting objectives (SO) are SO1 -- a decision-support tool for Agricultural Input Management with AI (AIM-AI) -- and SO2 -- a tool for Early Pest Detection with AI (EPD-AI). Tools integrate physical and statistical models, big-geodata (e.g., daily remote sensing), and AI. SO1 will merge recommendations for evapotranspiration-based soil-water balance irrigation scheduling, salinity leaching, and fertilization into a single framework. In SO2, an AI classifier

will estimate pest emergence in organic and conventional crops for timely response. AIM-AI and EPD-AI will be evaluated using extensive field data. Cooperative extension SOs will inform stakeholders of current research-based tools, knowledge, and on-farm practices (SO3), and disseminate knowledge from research SOs (SO4) through training (face-to-face and electronic), field days, publications, and smartphone and web apps. SO5 includes an undergraduate DA Fellowship to educate future farmers, and DA professionals and academics via student research, mentorship, and industry externships. Project success in fostering rural prosperity and environmental sustainability will be evaluated by stakeholders, scientists, and professional evaluators.

## Animal Health Component

Animal Health Component: 0%

## Research Effort Categories

| | |
|---|---|
| Basic | 5% |
| Applied | 70% |
| Developmental | 25% |

## Classification

| Knowledge Area (KA) | Subject of Investigation (SOI) | Field of Science (FOS) | Percent |
|---|---|---|---|
| 102 | 0110 | 2050 | 20% |
| 216 | 7210 | 1060 | 15% |
| 111 | 0210 | 1060 | 20% |
| 402 | 7210 | 2020 | 35% |
| 103 | 0399 | 2050 | 10% |

## Knowledge Area

[102] Soil, Plant, Water, Nutrient Relationships

[216] Integrated Pest Management Systems

[111] Conservation and Efficient Use of Water

[402] Engineering Systems and Equipment

[103] Management of Saline and Sodic Soils and Salinity

## Subject Of Investigation

[0110] Soil

[7210] Remote sensing equipment and technology

[0210] Water resources

[0399] Watersheds and river basins, general

## Field Of Science

**United States Department of Agriculture**
**Project Initiation**

[2050] Hydrology

[1060] Biology (whole systems)

[2020] Engineering

## Keywords

artificial intelligence; big data; precision agriculture; irrigation; salinity; nutrient; pest;

## Goals / Objectives

This project will lay the foundation for a long-term shift (10-20 years after the project) to highly-automated mechanized farm management systems (irrigation, nutrient, salinity, pest), while improving currently used technology in the short-term (during the project) and medium-term (5-10 years after the project). Colorado River Basin and Salinas River Valley farmland will be used as study areas. The project comprises four supporting objectives (SO):SO1 (Applied Research). Develop and evaluate algorithms for Agricultural Input Management with Artificial Intelligence (AIM-AI) that will merge available and novel models for evapotranspiration-based soil-water balance irrigation, nutrient application, and soil salinity management under a single Artificial Intelligence (AI) framework. Short-term: i) evaluate and integrate available decision-support models into a single AI platform; ii) test AIM-AI with current irrigation systems (typically delivering uniform prescriptions across a field) and on variable rate (VR) fertigation systems for its ability to save water, reduce environmental impacts, and sustain yields; and iii) employ hydrological modeling to evaluate the feasibility and benefits of large-scale adoption of automated VR management. Medium-term, the tool will be used to enable growers to shift, where suitable, to automated VR systems. Long-term, with refinements, AIM-AI offers to transform system-wide agricultural resource management over the entire western U.S.SO2 (Applied Research). For this objective, algorithms for early pest detection with AI (EPD-AI), will use very high-resolution remote sensing and other geodata, including spatial weather data. The EPD-AI offers a hierarchical, probabilistic alert for emergence of a generalized disease, pest, or weed problem, as well as targeted pests. Short term, EPD-AI will serve as a supplement to current scouting practices for pest detection. Long term, EPD-AI will be integrated with (semi-) automated pest management systems.SO3 (Cooperative Extension [CE]). Establish a multi-state CE network based on current and new collaborations between project investigators and local extension personnel to develop training programs that will reduce the gaps between state-of-the-art tools and knowledge and ongoing on-farm practices.SO4 (Cooperative Extension). Propagate the developed knowledge from SO1 and SO2. Translate AIM-AI and EPD-AI into user friendly web interfaces, including a novel smartphone app called FutureFarmNow, engage with private companies so that they can incorporate our open-access codes into their own tools. Establish a training program to educate growers and other relevant stakeholders on the Digital Agriculture (DA, i.e., the transdisciplinary application of high-performance computing and hyper-dimensional data in agricultural sciences) tools and knowledge generated from the project. Short-term, stakeholders will be trained to use FutureFarmNow and other developed tools. Medium- and long-term, training will continue to consolidate stakeholder knowledge on DA, to introduce new tools and innovations, and to aid the shift from traditional to DA management.SO5 (Education). Create highly skilled future leaders in the fields of DA, irrigation engineering, and agro-environmental management through Education, mostly of undergraduate students. The USDA and state agencies have highlighted the need to recruit more young people into the agricultural workforce. The US agricultural workforce has been aging for decades. In California, for example, where most farms are family-run, the average farmer age went from 56.8 (2002) to 60.1 (2012). This research project presents an opportunity to recruit a new generation of students, including data science-oriented undergraduate students, into careers in agriculture. To accomplish this, we will establish a Digital Agriculture Fellowship program for undergraduate students from UCR and our partnering institutions (University of Arizona, Colorado State University, Duke University, and University of Georgia).

## Project Methods

**United States Department of Agriculture**
**Project Initiation**

Research methods for the development of algorithms for Agricultural Input Management with AI (AIM-AI) and for early pest detection with AI (EPD-AI). The project will create and maintain a geodatabase to integrate field collected ground-truth vector data with raster data (e.g., satellite imagery, digital elevation models, spatial weather grids). Ground data will include: legacy data (e.g., soil, soil-water, water, weather) and project measurements (e.g., soil, soil-water, plant leaf/canopy sensor and laboratory analyses, eddy-covariance data, crop yield data, pest incidence). Satellite data will include ECOSTRESS, Landsat 8, Sentinel, Venμs, and the 0.8 to 5-m resolution daily Planet Labs. The artificial intelligent framework will include the following research thrusts: 1. Integration of multimodal data with tensor-based methods; 2. Deep learning models; 3. Incorporation of physical models; 4. Real-time streaming adaptation. Development of AIM-AI, project years (Y) 1 and 2 will integrate established techniques and models for: i) land use, crop classification and phenotyping; ii) rootzone soil texture, hydraulic properties, salinity, and topsoil water content mapping; iii) crop water requirement estimation; iv) salinity leaching estimation; v) nutrient estimation; vi) rootzone soil-water-solute balance; and vii) irrigation and fertilization scheduling optimization. For i), algorithms to estimate land-use, field boundaries, crop type, growth stage, and irrigation methods will be used. For ii), mapping algorithms that integrate geodata and soil databases with new soil data collected at thousands of locations. Networks of soil moisture sensors will calibrate topsoil water content models using remote sensing data and produced soil texture maps. For iii), the project will use the Simplified Surface Energy Balance operational algorithm using satellite thermal data and data from weather station networks. The ECOSTRESS evapotranspiration product will be fused with higher resolution multispectral imagery. For iv) hierarchical set of process-based mechanistic models that describe root-zone water flow, salt transport, and their combined effect on crop water uptake will be used. For v), plant growth status - from (i) and crop-specific N demand curves will inform a remote sensing-directed N budget. Remote sensing model calibration and evaluation will be informed by using N-rich strips and other ground-truth. For vi) Kalman filtering-type scheme will assimilate sensor-derived near-surface soil moisture data into the models' soil profile boundary conditions in (iv) and (v). Hundreds of soil moisture sensors (down to 1.5 m) will be used to train and evaluate the soil-water balance. For vii), the project will improve available formulations for irrigation and fertigation scheduling for field-wide and site-specific management on several irrigation delivery systems. Field experiments will evaluate and refine the AIM-AI algorithms. The project will investigate the potential benefits of mechanized automated long-term site-specific management using the Soil and Water Assessment Tool at selected watersheds in the Colorado River Basin. Model calibration and evaluation will use historic streamflow and groundwater and soil moisture observations. High resolution AIM-AI products will also be used to model calibration and evaluation, then linked to a stochastic dynamic programming model of irrigated agriculture which will build upon previous models developed by the project investigators. Thirty-year climate change projections will guide what-if analyses and upscaling the impacts of agriculture management practices identified at field scale to watershed scale. EPD-AI calibration will use both ground data from controlled field experiments and on-farm surveys. The experiments will be carried at one research station each in the Coachella and Imperial Valleys and in Orange County (CA). Plots will be grown organically (to ensure pest pressure), with rotations of selected crops. Plots surveys will log pests, and pest damage. Pest locations will be tagged with a hand-held GPS, classified by name in a scouting smartphone app, and photographed. Concurrently with the surveys, UAV will record aerial hyper (i.e., <5cm) resolution visible, near-infrared, and thermal reflectance. On-farm surveys will be carried out the project team and by collaborators. The surveys will identify pests and pest damage in vegetable, tree, and field crops at 50 or more organic and conventional sites. Location, name, and photo of any observed pest will be recorded. EPD-AI will use the AIM-AI geodata and analytical framework. Weekly Planet's SkySat imagery (0.72-m resolution) will also be acquired for the EPD-AI controlled field experiments. Remote sensing data time-series, National Weather Service data, and the soil maps and soil-water balance from AIM-AI will train the EPD-AI classifier to identify spatial anomalies that correspond to damage from pests and calculate a probability that the anomaly is caused by a specific (or unidentified) pest, while accounting for known weather-based pest models. Spatiotemporal imagery anomalies may also reveal a soil-related issue, irrigation or other human-related management malfunctions, or localized nutrient stress, and the probability of anomalies being non-pest will rely on soil maps and other spatial covariates in moving neighborhood analyses. UAV and smartphone photography data will be tested to improve EPD-AI predictions. Spatial cross validation will test EPD-AI algorithms. Validation of EPD-AI will be carried out at the sites previously used for calibration and new sites.Cooperative extension (CE) methods include: Training will

consist of interactive classes with Q and A sessions. Events will be live-streamed and made widely available on the project's YouTube account. Participants will receive business-card sized handouts with key messages and a QR code to the presentation materials on the project's website and mirrored by participating institution CE services. The developed app(s) will be based on an interactive WebGIS system consisting of two parts: a server-side back end and a client-side front end. The back-end runs on our servers and has access to AIM-AI and EPD-AI outputs. The front end will be an iOS app. Design criteria will always emphasize keeping the app(s) engaging, dynamic, and easy-to-use. Users will receive automatic notifications and will need to open the app only to enter certain information. App(s) training material will be delivered through a series of YouTube video tutorials and online instructions. Field days will be live-streamed with video stored on the project's YouTube channel (to be determined). An independent evaluator will evaluate CE methods by tracking the number of events and attendees, collecting post-survey data about the quality, usefulness, and relevance of the information presented, and measuring web-site use by stakeholders. If applicable, the evaluation will also monitor the how the app is used in the decision-making process, and the longer-term agricultural outcomes of those who utilize the app.Education methods will include a new fellowship program for undergraduate students with the following efforts: 1) Summer research program including professional development activities and a symposium; 2) Academic year research and activities (e.g., student-led research, annual symposium); 3) Externships at the project's industry partners; 4) International conference participation with mentor. An independent evaluator will evaluate education methods through online surveys, interviews, and focus groups with participating students. The evaluation design will be an explanatory mixed methods design, where quantitative survey data collected from students will be analyzed, with quantitative patterns then used to inform the development of interview or focus group protocols that aim to explain these patterns.