



# Environment and Natural Resources Trust Fund

## 2021 Request for Proposal

### General Information

**Proposal ID:** 2021-266

**Proposal Title:** Sustainable Irrigation Management: Expanding a Statewide Web Application

### Project Manager Information

**Name:** Bryan Runck

**Organization:** U of MN - College of Food, Agricultural and Natural Resource Sciences

**Office Telephone:** (612) 301-2532

**Email:** runck014@umn.edu

### Project Basic Information

**Project Summary:** This project will promote responsible use of Minnesota's limited groundwater resources through the expansion of the existing Irrigation Management Assistance tool into a statewide, mobile-compatible web app.

**Funds Requested:** \$1,519,000

**Proposed Project Completion:** 2024-12-31

**LCCMR Funding Category:** Water Resources (B)

### Project Location

**What is the best scale for describing where your work will take place?**

Statewide

**What is the best scale to describe the area impacted by your work?**

Statewide

**When will the work impact occur?**

During the Project and In the Future

## Narrative

### **Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.**

Water quantity and quality are projected to become increasingly severe concerns for crop production and environmental quality in Minnesota (Hatfield et al. 2018). Periods of water deficit can cause crop yield loss and leave unused soil nutrients exposed to potential leaching. Seasonal excesses of water can cause damage from in-field water logging, off-farm peak flows, and water quality degradation. Climate change within the region is expected to affect the frequency and severity of these extremes. As a result, we need practical approaches to help mitigate the concerns associated with too much and too little water in agriculture.

Irrigation - both traditional and non-tradition forms - presents both a challenge and opportunity for the agriculture-water nexus across Minnesota. Since 2002, the use of groundwater for irrigation has increased by more than 33% across Minnesota, such that by 2017 more than 611,000 farm acres in the state were irrigated (USDA 2017). As water management becomes increasingly important, it's anticipated that the number of farmers using irrigation will increase even in traditionally rainfed farming areas (Baker et al. 2012). This increase in groundwater use could have a negative impact on groundwater levels and the quality of streams if not effectively managed.

### **What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.**

Farmers want to improve their irrigation management practices to enhance crop production and water outcomes. Since 2016, the LCCMR-funded Irrigation Management Assistant (IMA) online tool has been adopted by over 100 regular users in the Little Rock Creek Groundwater area and 5-county expanded areas of Hubbard, Becker, Wadena, Otter Tail and Todd counties. These users rely on IMA to schedule irrigation for 5 different crops (corn, soybeans, alfalfa, potatoes, and edible beans) covering roughly 6,500 acres. The success of IMA in these regions and interest shown by other SWCD's and growers throughout MN revealed the need to expand it to a state-wide offering. Our goal is to improve irrigation management across Minnesota by advancing the IMA tool.

Specifically, to support improved irrigation management, we will:

- 1) expand the geographic coverage of the IMA tool to the entire state of Minnesota,
- 2) expand and improve the input data and crop models of the IMA tool so it is more useful for farmers, covering a wider array of irrigation approaches, including recycled drainage water
- 3) increase tool adoption by engaging farmers, SWCD staff, and crop consultants through extension and outreach.

### **What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?**

This project aims to reduce the groundwater use to levels that are sustainable over the long run and improve water quality in Minnesota. An accurate, easy to use, accessible and economically viable online irrigation scheduling tool for growers will help us achieve the ultimate goal of groundwater protection. Specifically we will:

- Develop a statewide-version of the irrigation management assistant (IMA) tool,
- Improve the prediction and forecast accuracy of the irrigation tool through crop modeling, low-cost soil moisture sensing systems, and state-of-the-art weather forecasting,
- Increase adoption of irrigation scheduling through nine field days and nine IMA workshops throughout the state.

## Activities and Milestones

### Activity 1: Expand the geographic coverage of the Irrigation Management Assistant databases and mobile application

**Activity Budget:** \$332,332

**Activity Description:**

The current Irrigation Management Assistant tool relies on detailed public soils and climate data to make irrigation recommendations. To give more growers access to the IMA tool, we need to expand the spatial coverage and accessibility of these data.

Currently, the IMA tool uses the gridded Soil Survey Geographic Database (gSSURGO) for information on site-specific soil physical properties such as soil texture, soil water holding capacity and field capacity. For climate data, the IMA tool uses the National Centers for Environmental Prediction forecast system data. We will expand the geographic coverage of these datasets within the IMA to the entire state of Minnesota. This will involve updating the system architecture and software interfaces so that they are interoperable with the tools supported by the cutting-edge GEMS agroinformatics platform developed and maintained by the University of Minnesota. Furthermore, we will improve the precipitation and evapotranspiration estimates with state-of-the-art data from the GEMS-IBM Weather Company partnership, which will improve precipitation estimates and forecasts for the tool. Also, in response to farmer feedback, we will improve the user interface to accommodate the new models described in Activity 2.

The end result will be a Minnesota-wide irrigation management assistant database and interface.

**Activity Milestones:**

Description	Completion Date
Provide scaled, limited release for 5 of the heavily irrigated counties	2022-04-30
Updated system architecture and interfaces to interoperate with GEMS tools and IBM weather	2022-07-31
Integrate public datasets into statewide databases to drive IMA tool	2022-12-31
Full integration of IBM Weather Company data into IMA tools	2023-04-30
Final updated interfaces to allow for sustainable statewide irrigation scheduling	2024-04-30

### Activity 2: Intelligent agriculture water management using sensors, crop models and machine learning

**Activity Budget:** \$877,602

**Activity Description:**

To improve the accuracy of the IMA tool in predicting the soil water status for irrigation scheduling, and to make it a “smart water management tool” that is self-predictive, real-time sensor data, weather data, crop models and machine learning techniques will be integrated. Specifically, we will:

-Deploy 150 sensor nodes that measure soil temperature, soil moisture, air temperature, humidity, barometric pressure, vapor pressure, canopy temperature, and photosynthetically active radiation will be installed in 20 grower fields and 4 UMN research fields. This data will help develop and validate models of crop productivity and water management.

-Integrate sensor data with state-wide data: Data will be live streamed to the GEMS agroinformatics platform and integrated to the state-wide data described in Activity 1. GEMS has state-of-the-art data security and has successfully passed security audits by Fortune 500 agricultural companies, who store sensitive business data on the platform.

-Bulk aerodynamic model will be developed to predict the crop water use and stress based on the crop canopy temperature and climate data.

-Train machine learning models: Sensor data will be combined with modeled data to calibrate machine learning models of crop phenology, water demand, and drainage flow.

**Activity Milestones:**

Description	Completion Date
Establish irrigation sites with 150 in-field sensor nodes at farmer and UMN sites	2022-04-30
Integrate live sensor data with statewide data from Activity 1	2022-10-31
Complete aerodynamic model to predict crop water use and stress from canopy and climate data	2023-12-31
Final machine learning models to improve recommendations and sustainability of irrigation management	2024-12-31
Manage 150 in-field nodes across all sites to ensure on-going data collection	2024-12-31

**Activity 3: Train farmers and their advisors in sustainable water management, the IMA tool, and sensing systems for water conservation**

**Activity Budget:** \$309,066

**Activity Description:**

Currently, the Irrigation Management Assistant pilot tool has more than 100 regular users covering 5 different crops across roughly 6,500 acres. To increase adoption of the tool and to make sure that growers understand how to use the tool for sustainable water management, we will use multiple channels for outreach and education:

1. Field day and workshop: During the course of this project, we will organize a field day each summer at three locations to demonstrate the technologies and benefits of water conservation practices. We will also organize a workshop each winter at three locations to provide hands-on training for extension educators, SWCD staff, crop consultants and others who directly train or help farmers in their management.
2. Extension publications: Extension bulletins, factsheets and blogs will be developed to reach a large audience of growers, consultants, extension educators, general public, state and federal agency personnel.
3. Conferences and other events: We will also demonstrate the outcomes of the project at other local field days, workshops, irrigation clinics, and local, national and international conferences.

Content of the extension and outreach will include tool use, conservation practices, input data and models, and data security and privacy.

**Activity Milestones:**

Description	Completion Date
Train farmers and local government units (SWCD's) in use of IMA tool and sensing system	2021-02-28
Train farmers and local government units (SWCD's) in use of IMA tool and sensing system	2022-02-28
Prepare and deliver field days year 1	2022-08-31
Train farmers and local government units (SWCD's) in use of IMA tool and sensing system	2023-02-28
Prepare and deliver field days year 2	2023-08-31
Prepare and deliver field days year 3	2024-08-31



## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Vasudha Sharma	University of Minnesota	Extension Irrigation Specialist - lead research and outreach; support design of node deployments and redesign of the tool; oversee the installation of sensing systems lead farmer fields	Yes
Jeffrey Strock	University of Minnesota	Soil Scientist and water management specialist; support design of node deployments and redesign of the tool; oversee the installation of infrastructure at the three experiment stations	Yes
Ali Rashid Niaghi	University of Minnesota	Lead the development of bulk aerodynamic model and support sensor development and machine learning model development	Yes
Phil Pardey	University of Minnesota	Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy	Yes
Lindsay Pease	University of Minnesota	Support extension and oversight of the installation of sensing systems on lead farmer fields and at NWROC in Crookston	Yes
Joel Larson	University of Minnesota	Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy	Yes
Gerry Maciej	Benton County Soil and Water Conservation District	SWCD staff will provide direct technical support to farmers; promote water conservation practices; assist in extension and outreach activities	No
Darren Newville	East Ottertail County SWCD	SWCD staff will provide direct technical support to farmers; promote water conservation practices; assist in extension and outreach activities	No
Jeppe Kjaersgaard	Minnesota Department of Agriculture	Promote water conservation practices; assist in extension and outreach activities; liaise to MDA's Groundwater Protection Rule and other groundwater protection activities.	No

## Long-Term Implementation and Funding

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?**

Long-term funding will come from three sources. First, we will use some modest funds through the College of Food, Agriculture and Natural Resource Sciences (CFANS) to maintain access to GEMS and will also work with the UMN Foundation to take donations. The on-going costs of the system are estimated at \$15,000 per year. We believe we can cover around \$10,000 per year based on the existing funding structure with donations. Second, we will seek fixed funds from the Federal government in partnership with the University of Minnesota's Water Resources Center. Lastly, we will seek additional private support from our industry partners such as PepsiCo who also have a stake in seeing agriculture and water resources improve in the state, as well as state commodity groups such as the Minnesota Corn and Soybean Growers Associations. Jointly, between these three pools of potential funding, we feel confident we will be able to cover the on-going costs of the statewide IMA tool.

## Project Manager and Organization Qualifications

**Project Manager Name:** Bryan Runck

**Job Title:** Geocomputing Scientist

**Provide description of the project manager's qualifications to manage the proposed project.**

Dr. Bryan Runck is a geocomputing scientist with the GEMS Agroinformatics Initiative at the University of Minnesota - a jointly founded initiative between the College of Food, Agricultural, and Natural Resource Sciences and the Minnesota Supercomputing Institute. He holds an M.S. in the Applied Plant Sciences from the University of Minnesota's

Department of Agronomy and Plant Genetics, and a PhD in Geography and minor in Computer Science focused on geocomputing. Broadly, Dr. Runck studies and applies geocomputing techniques to address complex food, agriculture, and environmental challenges. He has published over 20 peer-reviewed publications in top journals such as Nature Climate Change, Crop Science, and Global Biogeochemical Cycles, and been invited to speak at Harvard, the American Society of Landscape Architects, and the University of Hawaii - Manoa. He has played key roles in projects that have received over \$2 million in funding, including funding from the National Science Foundation and the United States Department of Agriculture.

Dr. Runck currently leads a lab consisting of electrical engineers, biosystems engineers, and computer scientists. They have extensive experience deploying sensing systems in the field (over 600 sensors deployed to date with live telemetry) and collecting, integrating, and analyzing live streams of data from multisensor nodes. His team has deployed sensing systems in agricultural contexts across North America and sub-Saharan Africa, as well as for environmental monitoring on glaciers in South America. Over the past nine years, Dr. Runck has supported the management of 5 different projects that each involved teams of 10 or more researchers with over 60 people across the non-profit and for-profit agricultural community. He has both the technical expertise in software and hardware and, with his background on his family's corn and soybean farm near Lamberton, MN and training in agronomy, the knowledge of agriculture to successfully manage this project.

**Organization:** U of MN - College of Food, Agriculture and Natural Resource Sciences

**Organization Description:**

The University of Minnesota, founded in the belief “that all people are enriched by understanding; is dedicated to the advancement of learning and the search for truth; to the sharing of this knowledge through education for a diverse community; and to the application of this knowledge to benefit the people of the state, the nation, and the world.” This mission is aptly illustrated in the Irrigation Management Assistant tool. This information serves farmers, crop advisors, and policymakers in understanding irrigation water management approaches to select for their purposes. The result of this work is to provide information that supports agriculture in Minnesota transitioning toward more sustainable production practices.

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Senior Personnel		Bryan Runck Oversee project and particularly sensor and machine learning work done by Researcher 3, software developer, and undergraduate research assistants; coordinate work across ROC system and GEMS agroinformatics initiative; Oversee work at ROCs; Provide system design feedback, development guidance, engage external stakeholders			36.5%	0.35		\$43,370
Post Docs		Ali Rashid Niaghi - Post Doc 1 who will be performing the bulk aerodynamic modeling and supporting machine learning work and sensor development			25.4%	2.1		\$170,064
Researcher		TBD (Pease) Will perform extension and outreach activities and field work associated with sensing system installation			31.8%	0.95		\$54,913
Graduate Research Assistant		RA will install and manage sensing systems and characterize differences in irrigation management. Will support Post Doc and researcher team in machine learning and aerodynamic modeling.			19.9%	3.25		\$170,042
Undergraduate Research Assistants		RAs will support field work and data collection; design and prototyping of hardware systems and the generation of ML models			0%	6.61		\$76,543
Senior Personnel		Jeff Strock - Soil Scientist and water management specialist; support design of node deployments and redesign of the tool; oversee the installation of infrastructure at the three experiment stations			36.5%	0.04		\$5,684
Senior Personnel		Lidsey Pease - Support extension and oversight of the installation of sensing systems on lead farmer fields and at NWROC in Crookston			36.5%	0.18		\$22,427
Senior Personnel		Vasu Sharma - Extension Irrigation Specialist - lead research and outreach; support design of node deployments and redesign of the tool; oversee the installation of sensing systems lead farmer fields			36.5%	0.04		\$4,407



Senior Personnel		Joel Larson - Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy			36.5%	0.04		\$5,768
Senior Personnel		Phil Pardey - Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy			36.5%	0.04		\$10,040
Researcher		TBD (Sharma) - Will support extension and outreach activities and field work associated with sensing system installation			31.8%	0.18		\$15,085
Researcher		TBD (Runck) - Will perform database management and integration, API development, and machine learning integration			31.8%	1.33		\$141,055
Administrative Support		TBD - This volume and the tight timeline of the project mandate more extensive monitoring than the services routinely provided by the department. A 10% time program assistant is needed to oversee the co-pis' activities, including working with SPA to perform risk assessment and monitoring, ensuring timely delivery and review of invoices, acquiring progress reports and ensuring their review, resolving mid-project issues, monitoring compliance approvals, ensuring timely payments, and handling multiple departments. Providing support for professional Service contracts and any modifications. We are therefore requesting agency approval for a 10% Administrative Assistant as an administrative cost allowed under 2 CFR 200.413."			31.8%	0.35		\$31,508
Developer		TBD (Runck) - Will perform database management and integration, API development, and machine learning integration			31.8%	1.57		\$172,807
							<b>Sub Total</b>	<b>\$923,713</b>
<b>Contracts and Services</b>								
RESPEC	Professional or Technical Service Contract	RESPEC developed the original and currently manages the IMA tool. RESPEC will perform Activity 1 and integrate the science described in Activity 2 into the application. RESPEC provides a unique and one-of-a-kind set of professional services because of their on-going management of the IMA tool.		X		3		\$225,000

Particle Sensor Cellular Connectivity	Professional or Technical Service Contract	Annual cellular subscriptions per node are \$2.99 per device per month. 12months x 150 devices x \$2.99 x 3.5 years		X		0		\$18,837
GEMS-Weather Company Subscription	Internal services or fees (uncommon)	Cost of subscription to GEMS platform for secure data sharing and analysis capabilities along with GEMS weather company access. This provides access to real-time weather information that is integrated with real-time sensor information to increase water management sustainability.		X		-		\$75,824
TBD - Irrigation	Professional or Technical Service Contract	Professional services for installation of drip surface irrigation at research sites. Will cover labor, pipe, fittings, lay flat hose, drip tape, pump, filters, and other irrigation site setup items				-		\$20,000
Plot Fees	Internal services or fees (uncommon)	Plot fees are for experiments at Becker and Crookston Research and Outreach Stations. ~\$1500 per year over 4 years.				-		\$6,000
							<b>Sub Total</b>	<b>\$345,661</b>
<b>Equipment, Tools, and Supplies</b>								
	Equipment	150 Multifunctional Sensor Nodes	150 sensor nodes collecting agroclimatic and soil information in real time; each sensor node costs \$1000					\$150,000
	Tools and Supplies	Irrigation Repair Supplies	Supplies for repairs and field work such as flags, tape, new irrigation piping and various other supplies need for repair and field work					\$5,986
	Tools and Supplies	Extension Meeting Supplies	Extension supplies, renting tent, chairs, tables, room charges, and other meeting supplies for 3 field days per year and 3 workshops per year (total of 22 meetings).					\$25,200
	Tools and Supplies	Food for Extension Meetings	Food and non alcoholic refreshments that will be served at 6 events per year (total of 22 meetings) Estimated cost \$900 per meeting	X				\$19,800

							<b>Sub Total</b>	<b>\$200,986</b>
<b>Capital Expenditures</b>								
							<b>Sub Total</b>	-
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	Miles/ Meals/ Lodging	Travel for extension meetings and field work	Travel to 6 extension meetings per year (total of ~22 meetings) and regular checkups on field plots located at the Becker and Crookston Research outreach stations to manage sensor nodes and engage farmers in technology feedback. Expense will be expensed in accordance of the University of MN reimbursement rates and guidelines					\$34,640
							<b>Sub Total</b>	<b>\$34,640</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
	Printing	Extension Handouts	Materials for extension meetings run by Sharma and Pease. 6 meetings per year- total of 22 meetings. Estimated printing cost of \$182 per meeting					\$4,000
	Publication	Publication Costs	Costs of each paper for open source between 1000 and 1500. Will cover the costs of publishing approximately one paper per year for each co-PI, totally between 8-10 papers from the project.					\$10,000

							<b>Sub Total</b>	<b>\$14,000</b>
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$1,519,000</b>

## Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
<b>Contracts and Services - RESPEC</b>	Professional or Technical Service Contract	RESPEC developed the original and currently manages the IMA tool. RESPEC will perform Activity 1 and integrate the science described in Activity 2 into the application. RESPEC provides a unique and one-of-a-kind set of professional services because of their on-going management of the IMA tool.	Because RESPEC has built and maintained the system for over four years, they have a unique insight into how the software functions and how it can be expanded. Shifting development to another firm would increase costs by 4-6x and it is unlikely that any other development firms in town have such extensive experience with irrigation-based applications for agriculture. <b>This is a single source contract.</b>
<b>Contracts and Services - Particle Sensor Cellular Connectivity</b>	Professional or Technical Service Contract	Annual cellular subscriptions per node are \$2.99 per device per month. 12months x 150 devices x \$2.99 x 3.5 years	In order to get the data from the sensors deployed across the state, we require a month-to-month cellular subscription for each device. Without this subscription, we would need to pay a field technician and account for mileage for two to three times as many visits to the site. It also would limit the usefulness of the system for growers to make real-time irrigation decisions. Thus, this expense is absolutely critical.
<b>Contracts and Services - GEMS-Weather Company Subscription</b>	Internal services or fees (uncommon)	Cost of subscription to GEMS platform for secure data sharing and analysis capabilities along with GEMS weather company access. This provides access to real-time weather information that is integrated with real-time sensor information to increase water management sustainability.	This is a one-of-a-kind data product offering and covers the expenses of hosting and maintaining secure data. <b>This is a single source contract.</b>
<b>Equipment, Tools, and Supplies</b>		Food for Extension Meetings	Food at extension events ensures both a good experience by farmer and SWCD participants and also keeps them at the entire event, so they aren't leaving to get food elsewhere. This means that people are more receptive of the information and more focused on the materials.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
<b>State</b>				
			<b>State Sub Total</b>	-
<b>Non-State</b>				
			<b>Non State Sub Total</b>	-
			<b>Funds Total</b>	-

## Attachments

### Required Attachments

#### *Visual Component*

File: [2fcd4061-5fb.pdf](#)

#### *Alternate Text for Visual Component*

Figure shows how we will improve groundwater sustainability in Minnesota by enhancing the Irrigation Management Assistant tool in four steps: 1) expand IMA tool with a statewide data infrastructure, 2) improve data inputs with sensors and state-of-the-art weather forecasts, 3) improve the usefulness of the tool for farmers with better models to support decision-making, and 4) train farmers and SWCD's in sustainable irrigation management using the tool.

### Optional Attachments

#### *Support Letter or Other*

Title	File
Irrigators Assoc of MN Letter of Support	<a href="#">a3448d67-601.pdf</a>
MDA Letter of Support	<a href="#">21c5107e-182.pdf</a>
Benton SWCD Letter of Collaboration	<a href="#">730901ab-942.pdf</a>
East Otter Tail Letter of Collaboration	<a href="#">26b78dd5-995.pdf</a>

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Does your project have patent, royalties, or revenue potential?**

No

**Does your project include research?**

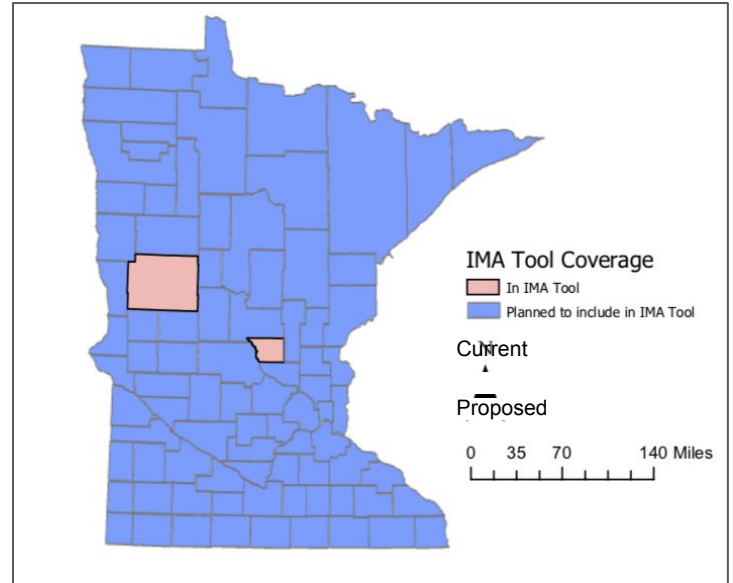
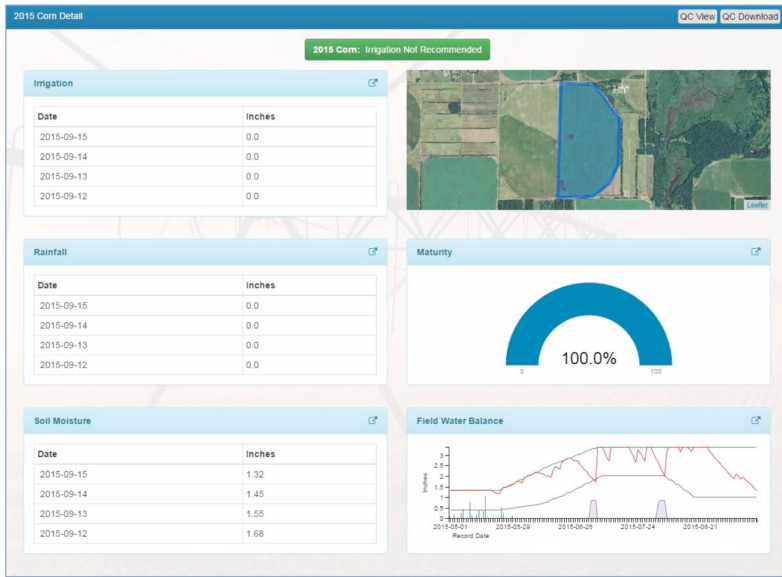
Yes

**Does the organization have a fiscal agent for this project?**

Yes, Sponsored Projects Administration

# Improving groundwater sustainability by enhancing the Irrigation Management Assistant Tool

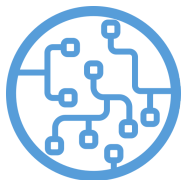
## 1. Expand IMA tool with a statewide data infrastructure



## 2. Improve the data inputs with sensors and state-of-the-art forecasts



## 3. Improve usefulness for farmers with better model decision-support



Machine Learning



Irrigation Models



Sustainable Irrigation Decision-making

## 4. Train farmers and SWCD's in sustainable irrigation management



Sustainable Irrigation Management Field Days



Sustainable Irrigation Technology Training