



Environment and Natural Resources Trust Fund

M.L. 2021 Approved Work Plan

General Information

ID Number: 2021-266

Staff Lead: Corrie Layfield

Date this document submitted to LCCMR: July 21, 2021

Project Title: Sustainable Irrigation Management: Expanding an Irrigation Web Application

Project Budget: \$1,139,000

Project Manager Information

Name: Bryan Runck

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

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Project Reporting

Date Work Plan Approved by LCCMR: July 20, 2021

Reporting Schedule: December 1 / June 1 of each year.

Project Completion: June 30, 2025

Final Report Due Date: August 14, 2025

Legal Information

Legal Citation: M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 04e

Appropriation Language: \$1,139,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to promote responsible use of Minnesota's groundwater resources by expanding an existing irrigation management assistance tool into a mobile-compatible web application for the top agricultural-producing counties in the state. This appropriation is available until June 30, 2025, by which time the project must be completed and final products delivered.

Appropriation End Date: June 30, 2025

Narrative

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 ~67 county, mobile-compatible web app.

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 wider 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 ~67 agriculturally dominated counties in 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 spatially extended 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 field days and IMA workshops

Project Location

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

Region(s): Central, SW, NW, Metro,

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

Region(s): Metro, Central, NW, SE, SW,

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

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

Activity Budget: \$237,912

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 ~67 agricultural counties in 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
Updated system architecture and interfaces to interoperate with GEMS tools and IBM weather	July 31, 2022
Provide scaled, limited release for 5 of the heavily irrigated counties	November 30, 2022
Integrate public datasets into databases to drive IMA tool (NWS or NOAA and gSSURGO data)	December 31, 2022
Full integration of IBM Weather Company data into IMA tools	April 30, 2023
Final updated interfaces to allow for sustainable irrigation scheduling	April 30, 2024

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

Activity Budget: \$683,043

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 75 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 ~4 grower fields and ~3 UMN research fields. This data will help develop and validate models of crop productivity and water management.

-Integrate sensor data with ~67-county data: Data will be live streamed to the GEMS agroinformatics platform and integrated to the 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 75 in-field sensor nodes at farmer and UMN sites	July 31, 2022
Integrate live sensor data with data from Activity 1	October 31, 2022
Complete aerodynamic model to predict crop water use and stress from canopy and climate data	December 31, 2023
Final machine learning models to improve recommendations and sustainability of irrigation management	December 31, 2024
Manage 75 in-field nodes across all sites to ensure on-going data collection	December 31, 2024

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

Activity Budget: \$218,045

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 (non ENRTF funds used for conferences).

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

Activity Milestones:

Description	Completion Date
Train farmers and local government units (SWCD's) in use of IMA tool and sensing system	May 31, 2022
Prepare and deliver 2-6 field days year 1	August 31, 2022
Train farmers and local government units (SWCD's) in use of IMA tool and sensing system	February 28, 2023
Prepare and deliver field 2-6 days year 2	August 31, 2023
Prepare and deliver 4-8 field days year 3 and 3.5	December 31, 2024

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
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
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
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
Joel Larson	University of Minnesota	Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy	No
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
Phil Pardey	University of Minnesota	Support design of node deployments and redesign of the tool; help operationalize long-term funding strategy	No
Ali Rashid Niaghi	University of Minnesota	Lead the development of bulk aerodynamic model and support sensor development and machine learning model development	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	No
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

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.

Extension and outreach are critical components of this project. In addition to the four engagement activities each year, we will disseminate our results through scientific publications and reports. Where private farm data is not of concern, we will share our data products via the state-of-the-art GEMSOpen data sharing platform. In all of our project press releases, media interactions, signs, publications, event advertisements & invitations, websites, newsletters, printed materials, presentations, and social media communications, we will acknowledge ENRTF as the funder with explicit use of the logo, attribution language, or tagging on social media. This information will impact farmers, SWCDs, crop consultants, and the scientific community.

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.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Developer		TBD (Runck) - Will perform database management and integration, API development, and machine learning integration			31.8%	1.25		\$141,175
Researcher		TBD (Runck) - Will perform sensor system management, database management and integration, API development, and machine learning integration			31.8%	1.47		\$129,342
Researcher		TBD (Sharma) - Will support extension and outreach activities and field work associated with sensing system installation			31.8%	0.15		\$15,085
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		Lidsey Pease - Support extension and oversight of the installation of sensing systems on lead farmer fields and at NWROC in Crookston			36.5%	0.7		\$22,427
Senior Personnel		Bryan Runck Oversee project and particularly sensor and machine learning work done by researcher, 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%	0.7		\$43,370
Undergraduate Research Assistants		RAs will support field work and data collection; design and prototyping of hardware systems and the generation of ML models			0%	0.35		\$2,746
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%	1		\$97,167
Researcher		TBD (Pease) Will perform extension and outreach activities and field work associated with sensing system installation			31.8%	1.01		\$52,168

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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
							Sub Total	\$677,951
Contracts and Services								
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		\$200,000
Particle Sensor Cellular Connectivity	Professional or Technical Service Contract	Annual cellular subscriptions per node are \$2.99 per device per month. 12months x 80 devices x \$2.99 x 3.5 years.		X		0		\$10,047
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		0		\$37,912
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
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
							Sub Total	\$273,959
Equipment, Tools, and Supplies								
	Tools and Supplies	Food for Extension Events	Food and non alcoholic refreshments that will be served at ~6 events per year (3.5 years total). Estimated cost ~\$900 per event.	X				\$19,800

	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.					\$25,200
	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					\$5,500
	Equipment	~80 Multifunctional Sensor Nodes	~80 sensor nodes collecting agroclimatic and soil information in real time; each sensor node costs ~\$1100. Because we manufacture these units custom, prices are subject to change +/-10% based on electronics parts supply and demand.					\$87,950
							Sub Total	\$138,450
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel for extension meetings and field work	Travel to ~6 extension events per year and regular checkups on field plots for 6 people 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
							Sub Total	\$34,640

Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
	Printing	Extension Handouts	Materials for extension events run by Sharma and Pease. ~6 events per year. Estimated printing cost of \$182 per event.					\$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
							Sub Total	\$14,000
Other Expenses								
							Sub Total	-
							Grand Total	\$1,139,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Contracts and Services - 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.	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. We will evaluate the costs on an annual basis to ensure on-going cost effectiveness and competitive pricing. We bid out work of this nature regularly and find RESPECs prices to be competitive or less expensive given their unique mix of experience in irrigation technology and software development. This is a single source contract.
Contracts and Services - Particle Sensor Cellular Connectivity	Professional or Technical Service Contract	Annual cellular subscriptions per node are \$2.99 per device per month. 12months x 80 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.
Contracts and Services - 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.	This is a one-of-a-kind data product offering and covers the expenses of hosting and maintaining secure data. We will evaluate the costs on an annual basis to ensure on-going cost effectiveness and competitive pricing. We have done external comparisons to other service providers of similar services and found GEMS Internal Sales contract price to be less than the cost of comparable products from IBM and Microsoft. This is a single source contract.
Equipment, Tools, and Supplies		Food for Extension Events	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. Events involve demonstrations/workshops/trainings/field days with a larger number of people. We've budgeted for a total of 22 events over 3.5 years. Historically, each event has an average attendance of 50-100 people. Because there is registration before hand, we can ensure that the right amount of food is ordered. Our estimate of \$900 is based on prior expenses for food from 2019 for extension events near Big Lake Minnesota, which had a total of \$790 for 70 people, or roughly \$11.30 per person for a buffet meal. If we assume on average there will be ~80 people per extension event, this results in a total of roughly \$900.

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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
			Non State Sub Total	-
			Funds Total	-

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	a3448d67-601.pdf
MDA Letter of Support	21c5107e-182.pdf
Benton SWCD Letter of Collaboration	730901ab-942.pdf
East Otter Tail Letter of Collaboration	26b78dd5-995.pdf
2021-266 Sust Irrigation Management - Peer Review Research Addendum	735e8686-167.docx
Background Check Certification Form	7cfbf475-eac.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

In order to perform the work under the reduced budget of 25% (\$1.519M to \$1.139M), while still delivering on the main project objectives, we have reduced the geographic scope by 25% of the project. The reduction in geographic scope will:

1. Allow research on the core ~67 agricultural counties in Minnesota, but will no longer cover counties that may transition to woody biofuels production requiring irrigation in the future.
2. Reduces the amount of labor required for model validation and calibration, enabling the reduction in FTE devoted to undergraduate, graduate student, and staff salary.
3. Decreases the number of sensors required for the project, which are shown as a reduction in the hardware budget for the project.
4. Decreases the data storage costs and compute costs for external computing services as well.

Proposal language throughout has been changed to reflect this reduced scope. Specifically:

Activity 1: replaced “entire state of Minnesota” with “the top ~67 agricultural producing counties of the state”

Activity 2: Changed “150” to “75 sensor nodes” and “20 growers fields and 4 research fields” with “~4 growers fields and ~3 research fields”

Activity 3: No changes

Budget Summary: corrected Researcher 3 description from “Will perform database management and integration, API

development, and machine learning integration” to “Will perform sensor development and integration including on-going instrumentation support”

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you agree travel expenses must follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I agree to the UMN Policy.

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

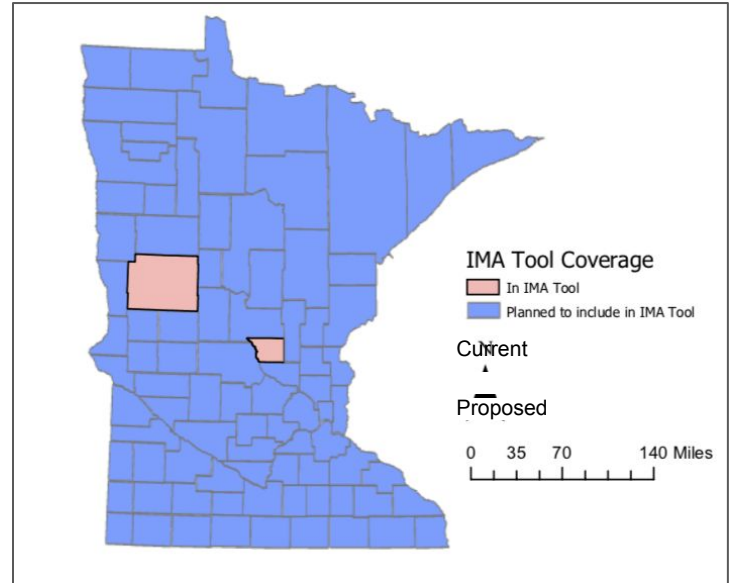
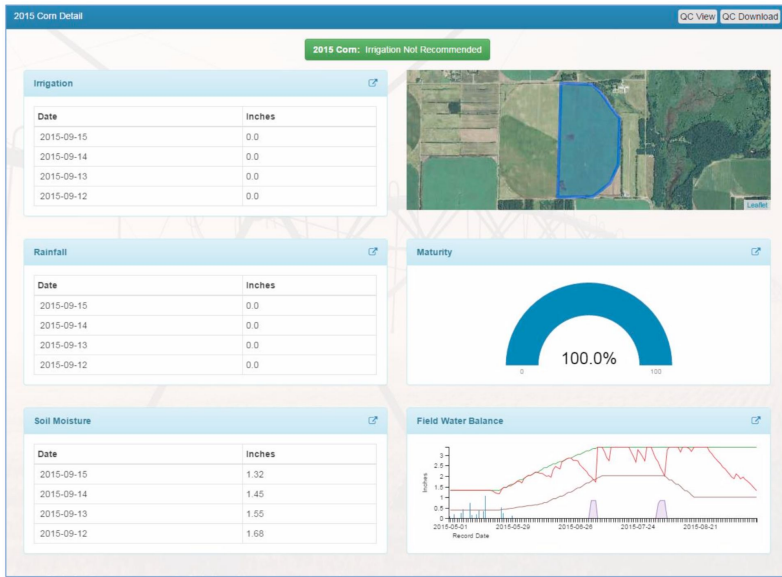
Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Improving groundwater sustainability by enhancing the Irrigation Management Assistant Tool

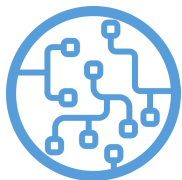
1. Expand IMA tool with a statewide data infrastructure



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

