Final Abstract

Final Report Approved on March 30, 2026

M.L. 2021 Project Abstract

For the Period Ending June 30, 2025

Project Title: Sustainable Irrigation Management: Expanding a Web Application

Project Manager: Bryan Runck

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

Mailing Address: 248 Ruttan Hall 1994 Buford Ave

City/State/Zip: St. Paul, MN 55108

Phone: (612) 301-2532

E-mail: runck014@umn.edu

Website: https://cfans.umn.edu/

Funding Source:

Fiscal Year:

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

Appropriation Amount: $1,139,000

Amount Spent: $1,122,002

Amount Remaining: $16,998

Sound bite of Project Outcomes and Results

The project expanded the Irrigation Management Assistant tool statewide, integrating real-time sensor networks, weather data, and machine learning to improve evapotranspiration prediction and irrigation scheduling. The tool is used across irrigated acres in Minnesota and enhances groundwater sustainability.

Overall Project Outcome and Results

Minnesota's farmers depend on irrigation to produce stable crop yields, but overuse of groundwater threatens long-term water supplies, lake levels, and stream health. Many irrigators lack field-specific, real-time information to guide when and how much to irrigate. This project addressed that challenge by expanding and improving the Irrigation Management Assistant (IMA), a science-based decision support tool that helps farmers apply water more efficiently while maintaining crop productivity.

We expanded the IMA tool from limited coverage to 87 counties across Minnesota. The system now combines real-time weather data, public soil maps, and field-level crop information to generate customized irrigation recommendations. We validated these data streams that feed directly into the IMA tool to ensure their accuracy. We also developed machine

learning methods to improve water use predictions and crop water needs under change weather conditions.

By 2024, more than 8,000 acres were actively using the IMA tool for irrigation scheduling. The project delivered outreach events between 2021 and 2025, including field days, workshops, and conference presentations, training hundreds of farmers, crop consultants, and local conservation staff. Educational materials emphasized both practical irrigation scheduling and the science behind water movement in soils and crops.

This project strengthens groundwater sustainability in Minnesota by reducing unnecessary irrigation while protecting yields. The expanded digital infrastructure provides a scalable, privacy-protecting platform that can support long-term water conservation policy and farm management decisions. Project findings were shared through peer-reviewed publications, Extension bulletins, public datasets, in addition to the IMA tool itself.

Project Results Use and Dissemination

Project results were shared through peer-reviewed journal articles, public datasets, conference presentations, Extension bulletins, and hands-on field demonstrations. From 2021–2025, the team delivered talks and workshops for farmers, SWCD staff, crop consultants, and agency personnel. Minnesota Crop News articles and media coverage expanded statewide reach. Field days at grower sites and research farms demonstrated the Irrigation Management Assistant (IMA) tool and sensor systems in operation.

Environment and Natural Resources Trust Fund

M.L. 2021 Approved Final Report

General Information

Date: April 13, 2026

ID Number: 2021-266

Staff Lead: Noah Fribley

Project Title: Sustainable Irrigation Management: Expanding a 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

Office Telephone: (612) 301-2532

Email: runck014@umn.edu

Web Address: https://cfans.umn.edu/

Project Reporting

Final Report Approved: March 30, 2026

Reporting Status: Project Completed

Date of Last Action: March 30, 2026

Project Completion: June 30, 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? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & 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	Approximate 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	June 30, 2025

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:

- 50 or more sensor 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	Approximate Completion Date
Establish irrigation sites with 50 or more 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, 2024
Manage 50 or more in-field nodes across all sites to ensure on-going data collection	December 31, 2024
Final machine learning models to improve recommendations and sustainability of irrigation management	June 30, 2025

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	Approximate 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 4	June 30, 2025

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
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 work 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	$ Amount Spent	$ Amount Remaining
Personnel										
Developer		Schulz (Runck) - Will perform sensor system management and research on hardware systems for bulk aerodynamic modeling and machine learning modeling			24.43%	0.75		$72,514	-	-
Researcher		TBD (Runck) - Will perform sensor system management, database management and integration, API development, and machine learning integration			24.57%	0.61		$56,206	-	-
Researcher		Malchow (Sharma) - Will support extension and outreach activities and field work associated with sensing system installation			24.27%	0.05		$21,114	-	-
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			0%	0		-	-	-
Senior Personnel		Lidsey Pease - Support extension and oversight of the installation of sensing systems on lead farmer fields and at NWROC in Crookston - (Summer Salary)			26.83%	0.04		$12,367	-	-
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			26.71%	0.74		$110,402	-	-

Undergraduate Research Assistants		RAs will support field work and data collection; design and prototyping of hardware systems and the generation of ML models			0%	0.01		$285	-	-
Graduate Research Assistant		RA will install and manage sensing systems and characterize differences in irrigation, RA (Runck) will install and manage sensing systems and characterize differences in irrigation management. Will work with other RAs and researcher team in data engineering and machine learning modeling. management. Will work with other RAs and researcher team in machine learning and aerodynamic modeling.			45%	2.71		$247,807	-	-
Researcher		Reitmeier & Loss (Pease) Will perform extension and outreach activities and field work associated with sensing system installation			24.51%	0.57		$48,834	-	-
Researcher		Ranaivoson (Strock) will perform the bulk aerodynamic modeling, support machine learning, and sensor development and deployment			26.16%	0.94		$148,407	-	-
Researcher (field)		Severson (Sharma)will perform field work associated with sensing system installation and maintenance			24.56%	0.03		$19,333	-	-
Researcher (field)		Martin/Sherwin will perform field work associated with sensing system installation and maintenance			24.42%	0.01		$9,182	-	-
Reseacher (field)		Sellie (Sharma) will perform field work associated with sensing system installation and maintenance			24.56%	0		$925	-	-
							Sub Total	**$747,376**	**$747,376**	**-**
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		$151,248	$137,956	$13,292
Particle Sensor Cellular Connectivity	Professional or Technical Service Contract	Annual cellular subscriptions per node are $2.99 per device per month. 12months x 59 devices x $2.99 and GEMS Annual Sensing Subscription Fee		X		0		$15,641	$15,640	$1
Cloud Server Cost	Professional or Technical Service Contract	Amazon/Google web services or google cloud services provide compute and storage for the data systems. This will be roughly $1200 per year.				0		$3,932	$729	$3,203
Weatherbit Software subscription	Professional or Technical Service Contract	11/2021 - 06/2025 Monthly fee $625				0		$27,500	$27,117	$383
Shipping	Professional or Technical Service Contract	Shipping - to return and ship sensors for repair				0		$50	$46	$4
External Temporary Research Assistant (Runck)	Professional or Technical Service Contract	The external research assistant will be a temporary employee able to support firmware development, hardware management and refurbishing, and in-field device management. - Tom Glancy				2		$15,000	$14,975	$25
External Statistical Consulting	Professional or Technical Service Contract	Dr. Michael Kantar - Dr. Kantar will consult on statistical analysis, publication review and framing, and copy editing of manuscripts and reports. Dr. Kantar is a internationally recognized expert in agroecology and statistics who consults on an as-needed basis for specific projects.				0		$25,000	$25,000	-

							Sub Total	**$238,371**	**$221,463**	**$16,908**
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				$2,752	$2,752	-
	Tools and Supplies	Extension Meeting Rentals	Extension supplies, renting tent, chairs, tables ($4,500), room charges ($1,500), ~3 field days per year and ~3 workshops per year.					$700	$700	-
	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					$15,071	$15,051	$20
	Equipment	Caltronics ~59 Multifunctional Sensor Nodes	~59 sensor nodes collecting agroclimatic and soil information in real time; each sensor node costs ~$1500. Because we manufacture these units custom, prices are subject to change +/-10% based on electronics parts supply and demand.					$75,744	$75,744	-
	Equipment	Additional Sensor Equipment	We have rebudgeted additional funds for equipment in Years 2 and Year 3 to adapt data collection efforts so that they reduce state-wide model errors as much as possible. Devices to be purchased with cost					$53,172	$53,102	$70

			~$2,000 each in total and will include soil moisture sensors from Acclima, Rain Guages, Anemometers, and Wind Vanes from Davis Instruments, solar radiation sensors from Apogee, and loggers with telemetry from Particle. Cost includes manufacturing costs by Caltronics Design and Manufacturing based in Stacy, Minnesota.							
							Sub Total	**$147,439**	**$147,349**	**$90**
Capital Equipment										
							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					$5,814	$5,814	-
							Sub Total	**$5,814**	**$5,814**	**-**

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.					-	-	-
							Sub Total	**-**	**-**	**-**
Other Expenses										
							Sub Total	**-**	**-**	**-**
							Grand Total	**$1,139,000**	**$1,122,002**	**$16,998**

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.
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 59 devices x $2.99 and GEMS Annual Sensing Subscription Fee	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.
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.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount	$ Amount Spent	$ Amount Remaining
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....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, 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
Project Deliverables	693844d3-f10.pdf
Gall et al 2024	88cd4614-74c.pdf
Willison et al 2021	4170e21b-7a7.pdf
Runck et al 2021	afe380d6-376.pdf
Subedi et al 2025	a3a3f95f-e33.pdf
Kantar et al 2025	eb43ee12-0d6.pdf
Strock & Ranaivoson 2025	a4f0a298-b5a.pdf
Rozanov et al 2025	a60a5757-919.pdf
MidwestET-500 Dataset	73f95324-9b1.pdf
Runck et al 2024	c33b558d-5c5.pdf
Runck et al 2023	baf3058f-da6.pdf
Runck 2025 - Prototype Tool Blog	f66430d7-7dd.pdf
Becker & Sharma 2022 - MN Crop News Blog	fd052552-425.pdf
Sharma & Runck 2023 - IMA Blog	37d54b9a-913.pdf
Runck et al 2022 - IMA Privacy Blog	3334d919-dbb.pdf
Sharma 2025 - registration Irrigation Field Day	8f2694cd-14c.pdf
Sharma 2023 - Water management strategies irrigation blog	5e6eac11-a6d.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 understand that travel expenses are only approved if they 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 understand the UMN Policy on travel applies.

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

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

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	• Budget • Project Collaborators - Project Partner Info • Budget - Professional / Technical Contracts • Activities and Milestones • Budget - Personnel • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences	--ProjectCollaborators--Ali Niaghi has moved on from the project. The work is now replaced by a staff scientist. --Activities--We updated the number of sensors and costs to reflect inflation and supply chain disruptions. Funds reallocated from labor/extension. --Activities -- supply chain delays have cause us to shift Activity 2 timelines --Staff were updated and replaced with grad RA's due to increased labor costs. Increased project management oversight effort to account for less experienced developers.	June 1, 2022	Yes	June 3, 2022
2	Amendment Request	• Budget • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Printing and Publication • Activities and Milestones • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences	We have moved funds originally budgeted to support extension events into covering staff / RA salary and wages that increased to cost of living or merit based increases over the past two years. Professional services contracts have changed to allow us to hire support for technical publishing, statistics, and documentation services.	June 3, 2024	Yes	July 10, 2024
3	Amendment Request	• Budget • Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Budget - Printing and Publication	We have moved funds originally budgeted for extension events (travel, printing), conference travel, and remaining field deployment staff time to cover the remainder of the RESPEC contract for final updates to the IMA tool. These updates include changes in domain name, hosting, and versioning for the weather data providing.	May 30, 2025	Yes	August 14, 2025

4	Amendment Request	• Budget • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Attachments	We moved funds from the unspent RESPEC professional services contract that were unspent to cover additional travel and field expenses that the project accrued in completing field work in the Fall of 2024. Changes were made to budget personnel to match slight additional spend ($354).	February 23, 2026	Yes	February 26, 2026

Status Update Reporting

Final Status Update August 14, 2025

Date Submitted: February 23, 2026

Date Approved: February 26, 2026

Overall Update

The project successfully achieved all stated outcomes, expanding the Irrigation Management Assistant (IMA) tool across Minnesota while improving prediction accuracy and increasing adoption. We deployed multi-functional sensor nodes across grower fields and UMN research sites, collecting real-time agroclimatic and soil data. The IMA tool now integrates uses GEMS Exchange weather data, providing farmers with improved irrigation scheduling recommendations. Our machine learning models enhanced evapotranspiration predictions compared to the state-of-the-art. Extension activities exceeded targets, delivering field days and multiple workshops annually, training farmers, SWCD staff, and crop consultants in sustainable water management. The project directly addresses groundwater sustainability by helping irrigators reduce water use while maintaining crop yields. All major milestones were completed: (1) expanded geographic coverage with updated system architecture, (2) integrated real-time sensor data with crop models and machine learning, and (3) successfully trained hundreds of farmers and advisors.

Activity 1

Activity 1 successfully expanded the IMA tool's geographic coverage to 87 counties across Minnesota, achieving the project's primary goal. We updated the system architecture to interoperate with the GEMS services and integrated GEMS Exchange weather data to provide real-time, high-resolution weather data to support water balance models. The team integrated public datasets including NWS/NOAA precipitation and temperature data and gSSURGO soil information, creating comprehensive spatial databases for the expanded coverage area (Gall et al. 2025). The updated user interface provides farmers with intuitive, field-specific irrigation recommendations based on their crop type, soil conditions, and real-time weather and shows a crop model based on heat until accumulation (previously it was based on linear time). The final system architecture supports sustainable irrigation scheduling across diverse Minnesota agricultural landscapes, from sandy soils in central Minnesota to heavier soils in other regions while ensuring grower privacy (see Runck et al. 2022). This expanded infrastructure enables irrigators to access science-based irrigation scheduling, contributing to groundwater conservation and improved water quality. In 2024, we had over 8,000 acres using the IMA tool to schedule irrigation across the state.
(This activity marked as complete as of this status update)

Activity 2

Activity 2 successfully deployed multi-functional sensor nodes across approximately four grower fields and three UMN research fields (NWROC Crookston and other locations). Each node collects real-time data on soil moisture, soil temperature, air temperature, relative humidity, and other agroclimatic variables critical for irrigation decisions. We integrated live sensor data streams with Activity 1's database infrastructure, enabling dynamic irrigation recommendations. The team developed a high resolution temperature sensor to support a bulk aerodynamic to predict crop water use and stress. Machine learning models were trained to refine irrigation recommendations and predict field-specific water needs (Rozinov et al. 2025). The sensor network operated continuously throughout the project period. Maintenance and management of 50+ nodes across dispersed locations required significant coordination and travel. We also published papers reviewing data quality of the new data streams introduced into the tool in Activity 1 and evaluated how error propagates through different models to influence irrigation recommendations (Subedi et al. 2025).
(This activity marked as complete as of this status update)

Activity 3

Activity 3 exceeded expectations in training and outreach, conducting numerous field days, workshops, and training sessions for farmers, local government units, SWCD staff, extension educators, and crop consultants. We delivered 17 talks in 2021, 20 in 2022, 14 in 2023, 20 in 2024, and 11 in 2025 related to irrigation and nutrient management. The materials in these talks emphasized both the technology (sensors, app interface) and the underlying science (crop water requirements, soil-plant-atmosphere continuum). These activities directly contribute to the long-term adoption of sustainable irrigation management practices across Minnesota. Extension Specialist Vasudha Sharma and RESPEC representative Paul Senne led hands-on training sessions demonstrating the IMA tool, sensor technology, and sustainable irrigation principles. Field days showcased operational sensor nodes. Workshop topics included irrigation scheduling fundamentals, interpreting soil moisture data, using the IMA application, and implementing water-conserving irrigation practices. We produced extension publications, gave conference presentations, and engaged stakeholders through multiple channels. The high level of farmer and advisor interest led to additional engagement opportunities beyond the original plan. Training materials emphasized both the technology (sensors, app interface) and the underlying science (crop water requirements, soil-plant-atmosphere continuum). This activity directly contributes to long-term adoption of sustainable irrigation management practices across Minnesota.
(This activity marked as complete as of this status update)

Dissemination

Project findings were disseminated through peer-reviewed publications, datasets, conference presentations, Extension bulletins, field days, and media outreach. The team produced multiple scientific papers advancing digital agriculture, irrigation decision support, evapotranspiration modeling, and real-time geoinformation systems. Key outputs include Gall et al. (2024), Kantar et al. (2025), Rozanov et al. (2025a,b), Runck et al. (2024), Subedi et al. (2025), and related work integrating sensors, crop models, and machine learning. Results were also shared through national and regional conferences, including ASA-CSSA-SSSA Annual Meetings (2023–2025), CANVAS 2025, and the Minnesota Conference on Precision Agriculture.

Extension dissemination was extensive. Minnesota Crop News bulletins by Sharma, Runck, and collaborators (2022–2025) reached irrigators statewide. Field days and hands-on demonstrations at grower fields, the Sand Plain Research Farm, and outreach events delivered practical training on the IMA tool, sensor systems, and sustainable irrigation strategies. Additional press coverage, including Mohr (2022) and Minnesota Association of Wheat Growers (2025), among others, provided additional reach for the project.

See the attached documents for full list of outputs.

Status Update Reporting

Status Update June 1, 2025

Date Submitted: May 30, 2025

Date Approved: August 14, 2025

Overall Update
Since our last progress report, project 2011-266 has started to wind down finalizing research and application hosting. In the final month of the project, we will focus on project closeout. We have successfully managed through multiple changes in staffing and unprecedented inflation for materials to deliver on the objectives of the project. In particular, in addition to delivering a statewide version of the IMA tool, we have advanced the state-of-the-art in modeling, results which have been peer reviewed or will be under peer review soon.

Activity 1
Objective 1 has continued to go according to plan since December 2024 with the exception that during the on-going testing period, we found additional items that needed to be updated to ensure security and privacy compliance according to internal RESPEC policy. As anticipated, we require additional budget for the RESPEC portion of the project in the final month for the updated web application with new validated data streams. Activity 1 will be complete then by mid-June after these final changes.

Activity 2
- Papers Subedi et al. 2025 in Agrosystems, Geosciences & Environment on gridded data suitability compared to ground observations. Important because it verifies that the new data sources are of comparable quality for on-farm predictions.
- Co-edited special issue on computational design (Kantar et al. 2025) on the role that digital agriculture can play in enhancing cropping system sustainability
- Machine learning models built and tested using a knowledge-guided machine learning approach. Paper titled "Knowledge-Guided Tree-Based Models for Evapotranspiration Upscaling in the U.S. Midwest" in preparation for submission to Computers and Electronics in Agriculture. Results show that KGML methods are able to predict evapotranspiration for every location in Minnesota with an R2 of 0.85, RMSE of 51.284, and MAE of 9.046. These results need to be field validated in subsequent grants before inclusion into the IMA tool, but suggest that these methods could be suitable for improving overall estimates of ET for growers.
(This activity marked as complete as of this status update)

Activity 3
Our lead extension educator was on parental lead for the first 3 months of the calendar year. Graduate students participated in one extension event:

Elvir A. F. and V. Sharma. 2025. Optimizing Irrigation and Nitrogen Management for Sustainable Corn Production in Minnesota. Pope, Stearns, Swift, and Kandiyohi Counties Irrigators Clinic 2025. Spicer, MN. March 24th. 50 attendees
(This activity marked as complete as of this status update)

Dissemination
During this phase of the project, we have been focused on finishing research deliverables and writing papers. We will be submitting these papers through the remainder of the summer and then writing blog posts summarizing the results as they are accepted.

Blog posts:
Runck, B.C. (2025). A Prototype Tool for Integrating Agrometeorological Data Across Sources.

https://gems.umn.edu/news/prototype-tool-integrating-agrometeorological-data-across-sources

Papers

Subedi, S., et al. (in prep). Understanding the changing cropping calendar by exploring contemporary and historic AGDD in three crops in Minnesota. Crop Science.

Subedi, S., Runck, B, Sharma, S. (in prep). Remote Sensing-Based Estimation of Crop Coefficients (Kc) for Precision Irrigation Systems in Minnesota. Journal of the ASABE.

Razinov, A., et al. (in prep). Knowledge-Guided Tree-Based Models for Evapotranspiration Upscaling in the U.S. Midwest.

Additional Status Update Reporting

Additional Status Update March 20, 2025

Date Submitted: May 30, 2025

Date Approved: August 14, 2025

Overall Update
See June update

Activity 1
See June update

Activity 2
See June update
(This activity marked as complete as of this status update)

Activity 3
See June update
(This activity marked as complete as of this status update)

Dissemination
See June update

Status Update Reporting

Status Update December 1, 2024

Date Submitted: January 31, 2025

Date Approved: April 3, 2025

Overall Update

Since our last progress report, project 2011-266 has made substantial progress advancing the IMA tool and the underlying research. We have focused on ensuring the accuracy and stability of new water balance and growing degree day models into the tool in preparation for the new growing season. In research, we are nearing completion of multiple academic publications focused on the major aims of the project, with one paper published, one in review, and three more in preparation. Unfortunately, we lost our instrumentation specialist and one of our graduate research assistants in the last quarter of 2024. The project ensured appropriate documentation and handoff to other team members, so that work is on-going and on-track. Considered together, the project is on track for a successful, slightly under budget completion by the project end period.

Activity 1

We have continued our test of the new models and data pipelines supporting the expanded and updated Irrigation Management Assistant tool. This work has shown that the new systems are stable and ready for the next growing season. We have also piloted updates to the crop progress tracking widget to better fit the growing degree day models. We anticipate a smooth roll out of the new system for this next growing season. We anticipate that this work may require additional budget for RESPEC, and may require an amendment to that line in March to accommodate that work.

Activity 2

We had a successful field season this past year and collected data across Lamberton, Crookston, Becker, and Rosholt farms. Nodes were managed daily by team members and supported centrally from the UMN St Paul Campus for installation and decommissioning. We have integrated these data with the older datasets.
Our machine learning graduate assistant has made considerable progress on the knowledge guided approaches. Further, we have worked to compare our results with other emerging technologies such as MESONET measures and OpenET. There are three papers currently being drafted and we plan to submit for peer review.
Our longtime instrumentation engineer on the project has moved on to a new position. The bulk aerodynamic modeling portion of the project has led to a low cost, high resolution temperature delta sensing system to characterize latent heat fluxes. This system was deployed this past field season and the data are under review to see if they are suitable for publication.
In addition to the papers under draft, we have presented at the Annual Agronomy meeting and had two papers published in peer review journals focused on data quality and model evaluation.

Activity 3

We have continued to perform our regularly planned workshops reaching irrigators, crop consultants, and SWCD professionals across multiple events. These include demonstrations through the Minnesota Irrigator Program, presentation at field days, and individual engagements with SWCDs and irrigators.

Dissemination

In addition to the work through extension programming, we have published work on blogs, websites, academic journals, and presented at academic conferences. Following are relevant items:
Blog Posts
https://blog-crop-news.extension.umn.edu/2024/10/could-adding-irrigation-to-minnesota.html
https://blog-crop-news.extension.umn.edu/2019/01/soil-water-basics-for-irrigation.html

Website Updates
https://extension.umn.edu/soil-and-water/irrigation
Research Articles
Gall, L., Glancy, T., Kantar, M., & Runck, B. C. (2024). A tool for integrating agrometeorological observation data for digital agriculture: A Minnesota case study. Agricultural & Environmental Letters, 9(2), e20147.

Academic Presentations
Kechchour, A., Miao, Y., & Sharma, V. (2024, November). Evaluating the Potential Benefit of Integrated Precision Nitrogen and Irrigation Management for Corn in Minnesota. In ASA, CSSA, SSSA International Annual Meeting. ASA-CSSA-SSSA.

Subedi, S., Runck, B., & Sharma, V. (2024, November). Enhancing Irrigation Management in Minnesota through Actual Crop Evapotranspiration Estimation. In ASA, CSSA, SSSA International Annual Meeting. ASA-CSSA-SSSA.

Status Update Reporting

Status Update June 1, 2024

Date Submitted: June 3, 2024

Date Approved: July 10, 2024

Overall Update
Since our last progress report, project 2011-266 has made substantial progress advancing the IMA tool and research activities. In particular, we have focused on advancing the underlying science of the tool focusing on water balance and crop growth tracking. These scientific advances, after being validated, are deployed in models behind API's according to our initial architecture. This is allowing for the maintenance of grower privacy while allow the University to provide model-based best practice recommendations through the tool as knowledge improves. In line with past reporting, I've extended our approximate completion dates to the end of the project period (June 2025) to accommodate the delays we had with hiring and hardware procurement earlier in the project. Despite those delays, all project deliverables are on track for completion with multiple publications either submitted or nearing submission.

Activity 1
To accommodate new scientific models, the end date for updated interfaces has been extended to June 2025. We have incorporated technical writing services to enhance documentation and analysis, reallocating funds accordingly. The crop progress tracking widget in the IMA tool, previously based on a linear model, has been updated to reflect changes in crop models, now deployed via a RESTful API on RESPEC servers. The IMA tool continues to operate statewide, providing valuable data and support to users. Much of the work remaining on this sub-aim is focused on incorporating the final changes the models, ensuring on-going delivery of the IMA tool, and incorporating additional feedback from users.

Activity 2
We've had many accomplishments on this activity since the last report. We have submitted two papers for peer review. One focused on the real-time sensing system and the other on spatial variation in growing degree day models.

We also have developed a knowledge-guided machine learning model that outperforms state-of-the-art models on small training datasets. This season, we are expanding the training data and geographic testing scope. The anticipated completion date has been extended in line with what was indicated in the last report to account for the delays in hiring.

The bulk aerodynamic modeling system is undergoing field testing and data collection. Through a separate project, we were able to acquire a new ET sensor from LiCOR that will be used in side-by-side evaluation.

As described in the amendment request, we have moved funds to accommodate increased wages due to cost of living and merit-based increases in salary for staff and students on the project.

Activity 3
Outreach and extension activities continue as planned. Since our last report, we have had over 300 attendees at presentations or trainings for the IMA tool and irrigation management best practices. We also were apart of the Minnesota Irrigators Program (MIP) on March 6th, March 13th and March 20th 2024. Staples, MN (40 attendees)

Specific notable trainings and talks include:
- Sharma, V., (Author & Presenter), Kechchour, A., (Author) Miao, Y. " Precision irrigation and nitrogen management for enhancing water-nitrogen use efficiency " Minnesota Ag Expo 2024 Minnesota Corn Research and Promotion Council, Mankato, Minnesota, United States. (January 18, 2024). Invited. 50 contacts

- Sharma, V. (2024) Deficit Irrigation Management in Potatoes-Preliminary Data from the Study at Becker. Minnesota AreaII Potato Growers- 32nd Annual Educational Worshop. Saint Cloud, MN. (February 27, 2024). Invited. 30 contacts

- Sharma, V. (2024) Advancements in Irrigation Techniques: A Research Update. Irrigation Association of Minnesota Annual Convention 2024. Freeport, MN. (February 15, 2024). Invited. 100 contacts

Sharma, V. "Introduction to irrigation scheduling methods," Minnesota Irrigator Program University of Minnesota, Saint Cloud, Minnesota, United States. (March 6, 2024). 40 contacts

Dissemination
In addition to our outreach activities update, we have presented and published in multiple venues. Below is a brief summary:

Presentations
Sharma, V. (2024) Advancements in Irrigation Techniques: A Research Update. Irrigation Association of Minnesota Annual Convention 2024. Freeport, MN. (February 15, 2024). Invited. 100 contacts

Sharma, V. “Variable rate irrigation and nitrogen management for corn production.” 10thnnual Nitrogen Management Conference. Saint Cloud, MN. (February 13, 2024). 100 contacts

Sharma, V. (2024) Advancing Sustainable Agriculture: Research on Advanced Irrigation Management Techniques in Minnesota. East Ottertail Soil and Water Conservation District Irrigation Clinic. Thumper Pond, MN. (March 5, 2024). Invited. 50 contacts

Sharma, V. " The Field Water Cycle and Crop Water Use or Evapotranspiration," Minnesota Irrigator Program, Staples, MN. (March 6, 2024). 40 contacts

Publications
Runck et al (2024). Real-time Geoinformation Systems to Improve the Quality, Scalability, and Cost of Internet of Things for Agri-environment Research. arXiv preprint arXiv:2403.19477.

Status Update Reporting

Status Update December 1, 2023

Date Submitted: January 24, 2024

Date Approved: March 1, 2024

Overall Update
Since our last progress report, project 2011-266 has made considerable progress toward expanding the IMA tool, particularly on the research front. We successfully supported the tool over the summer of 2023, impacting over 5,850 acres in Minnesota and have clear plans for further tool enhancements over the winter. On the research side, we are fully staffed and research assistants are making consistent progress with preliminary results across all of our research objectives including the low cost bulk aerodynamic modeling, the machine learning to predict ET, and improvements in crop progress tracking with growing degree day models. This work has been shared with irrigators and conservation professionals through multiple extension venues, and with the broader scientific community at conferences. As we look into the next year, we anticipate moving toward publishable findings in research, though we anticipate needing to shift research timelines for the model research to end June of 2025 given the delays we had in hiring.

Activity 1
Since our last status report, we have deployed and monitored the updated web application for the full growing season. This has involved ensuring the application continues to operate as planned and responding to user queries and questions as they arise. In 2023, we had over 5,850 acres under active management with the tool.

Since the start of the project, we have listened to irrigators and conservation professionals about what changes they would like to see in the application and we will continue to do so over the winter season. In response to these, we have plans to update how crop progress is displayed. We have drafted interface changes based on research occurring in Activity 2 and will release these changes before the next growing season.

Activity 2
This activity is in full swing now as our graduate students and staff execute on research plans.

Data was collected at Becker, Rosholt, Crookston, and Lamberton this past field season. This includes environmental sensing and crop phenology data for updated crop progress tracking with the use of growing degree day models. Preliminary results of a new gridded growing degree day model were presented at the annual international meeting of agronomists, crop scientists, and soil scientists in October of 2023 and resulted in a best poster award.

We have built and deployed the prototype bulk aerodynamic modeling system and performed both lab-based and field-based evaluation of the system. A key property of the system is its ability to sense extremely fine resolution differences in temperature (<0.001 degree C). This hardware system will now support modeling and analysis work of the data for low cost ET estimation.

With the onboarding of our new masters student, we have a preliminary workflow using machine learning models to estimate ET and water balance. This workflow will be further developed through the winter and validated against field data.

Given the delay in hiring for this position, we anticipate requesting an amendment for an extension.

Activity 3
Extension events continue as planned. This includes delivering 2 field days since Sep 1, 2023, publishing 2 extension

blogs, performing 2 trainings. In total, these activities have reached ~1000 contacts.

We have also presented about our work on irrigation at multiple conferences. These include posters at the international agronomy meeting.

Field days:

- Organized the Sand Plain Research Farm Irrigation and Nutrient Management field day. 10th August 2023 (35 attendees)
- Co-organized the Pope County Soil and Water Conservation District (SWCD) Rosholt farm field day in collaboration with Pope County SWCD staff. 17th August 2023 (60 attendees)

Trainings:

- Organized Minnesota Irrigators Program (MIP) on March 1st, March 8th and March 15th 2023. Farmington, MN (35 attendees)
- Co-organized Regional Conservation Partnership Program (RCPP) Irrigation Workshop with MDA. July 17-18, 2023 (41 Attendees)

Dissemination

Our third aim describes in detail our extension and dissemination activites. More details about blogs and conference presentations:

Blogs:

- Sharma, V. (2023). Water management strategies to keep in mind while making irrigation decisions. University of Minnesota Extension. https://blog-crop-news.extension.umn.edu/2023/06/water-management-strategies-to-keep-in.html
- Sharma, V., & Runck, B. (2023). Interested in fine-tuning your irrigation decisions? Try the free online Irrigation Management Assistant (IMA) tool. University of Minnesota Extension. https://blog-crop-news.extension.umn.edu/2023/05/interested-in-fine-tuning-your.html

Conference Presentation:

- Subedi, S., +Sharma, V., & Runck, B. (2023) Assessing a New Gridded Gdd Model Against Mesonet Measures in the Upper Midwest United States [Abstract]. ASA, CSSA, SSSA International Annual Meeting, St. Louis, MO. https://scisoc.confex.com/scisoc/2023am/meetingapp.cgi/Paper/151335

Status Update Reporting

Status Update June 1, 2023

Date Submitted: May 30, 2023

Date Approved: June 2, 2023

Overall Update

Since our last progress report, project 2011-266 has continued to make consistent progress toward expanding the IMA tool. 1) Specifically, because of cost savings associated with architectural decisions, we have been able to release the IMA tool for the entire state of Minnesota, not just the originally planned 67 counties. We will continue to listen to users and update the application with their feedback through the remainder of the project using an agile approach. 2) We are in the process of testing the bulk aerodynamic prototypes and have hired on an excellent masters student who will start this fall on the machine learning and data science aspects of the project. As we continue forward in the project, our overall focus is on continued app updates in response to user feedback, expanding our educational reach, and continuing our data collection. As we look out into the next year, these activities will set us up well for finalizing the research, publishing, and outreach aspects of the project as we transition the app over for long term operations.

Activity 1

We continue to be ahead of schedule on Activity 1. We have completed the integration of weather and soils data from the University of Minnesota and have released the IMA tool as a statewide application. This goes above and beyond what the original intention was for the project, where we scoped the project for roughly 67 counties. Because of cost savings found in the use of the GEMS Exchange API's, we were able to reduce costs associated with data cleaning and wrangling. These savings were invested in expanding the geographic reach of the web application. We are in the process of gathering additional user feedback now on the statewide application and will incorporate this into the application for growing season 2024.

Activity 2

This activity is back on track now after managing through substantial staffing and supply chain challenges. In field season 2022, we successfully collected data across Lamberton, Becker, and Rosholt, Minnesota with the Dynamax probes. These data are being integrated into a common database for project team members by the PhD research assistant.

With the Caltronics manufactured systems in hand, we developed a standard operating procedure for device installation over the winter. These systems are being installed across Lamberton, Rosholt, Becker, and Crookston.

The bulk aerodynamic modeling system has been designed, components have been procured, and is in the final stages of prototyping before deployment this summer. This system relies on highly sensitive thermocouples deployed within and just above the crop canopy to estimate temperature gradients driving evapotranspiration. This work is being led by the Strock lab in Lamberton with support from the Runck lab in St. Paul.

Lastly, we have recruited a masters student who will start in the Masters of Geographic Information Science program. This student will begin this fall and has a strong background in data science and machine learning.

Activity 3

We have successfully completed the planned trainings of farmers and local government units (SWCDs) in the use of the IMA tool in addition to requesting feedback from them on how to improve the systems. We have delivered more than the 6 anticipated workshops over the past year. Specifically, we have delivered content on the IMA tool to approximately 400 irrigators, crop consultants, and SWCD professionals at 9 education and outreach events since September of 2022 as listed below.

- Sharma, V. "Irrigation Research Update: Lessons Learned from Irrigation Management Research in Minnesota" Minnesota Department of Natural Resources Month Water Appropriation meeting. (March 14, 2023).
- Sharma, V. "Sustainable Irrigation Management: Research Update". Sherburne County Soil Water Conservation District Lunch and Learn Event. Becker, MN. (March 7, 2023).
- Sharma, V. "Lessons learned from Irrigation Management Research in Minnesota". West Central Soil Water Conservation Districts. Greenwald, MN. (March 6, 2023).
- Sharma, V. "Irrigation Research Update". Irrigation and Nutrient management clinic. East Ottertail Soil water conservation district. New York Mills. (March 2, 2023).
- Sharma, V. "Introduction to irrigation scheduling methods," Minnesota Irrigator Program University of Minnesota, Farmington,

Dissemination

In addition to the extension and outreach activities in Activity 3, Dr. Sharma published a blog post in Minnesota Crop News blog overviewing the updates to the IMA tool and its statewide release.

Status Update Reporting

Status Update December 1, 2022

Date Submitted: November 18, 2022

Date Approved: November 23, 2022

Overall Update
Since our last progress report, project 2021-266 has continued to make consistent progress toward expanding the IMA tool into a 67-county application. We continue to be ahead of schedule. Specifically, we have 1) completed the release of the limited, updated app for piloting and testing, 2) have completed our first year of data collection successfully, 3) hired a PhD student to work on the data science parts of the project and support field data collection, and 4) have ramped up our dissemination by publishing information on social media, blog posts, and being featured across multiple popular press farm publications. Some setbacks have occurred: one of our two PhD students decided to not attend in late August. This means we need to repost this position for Fall 2023. We also have continued to have delays in hardware delivery, though hardware has been delivered as of early November for 2022. Overall, we continue to be on track for the project and the team is poised to begin preliminary data analysis this winter.

Activity 1
Building on our progress, we have continued to be ahead of schedule for Activity 1. Our architecture and interface designs preserve irrigator privacy while making UMN data and models available. We have completed the 5 county limited release for the Central Sands region. This release has focused on a targeted set of users for bug testing and incorporates improved weather and soils data. We have also started to prepare for incorporating new evapotranspiration and growing degree day models. The new PhD student has started to compare different models and their sensitivity to errors in inputs. This has led to the development of new Python code that will be used in both evaluation and research.

Activity 2
We continue to manage staffing and supply chain challenges, but are on track with all deliverables. This past season, we deployed Dynamax probes to fill in for the delayed hardware from Caltronics Design and Manufacturing. These probes were used to collect data at University of Minnesota Research and Outreach Centers. Caltronics Design and Manufacturing sensor nodes arrived at UMN in early November and are ready for field deployment in the 2023 growing season. Throughout this winter we will work to integrate data and perform preliminary analyses.

Literature review has been completed for the bulk aerodynamic modeling. This will inform additional prototyping, development, and field deployment of devices in 2023.

In late summer, we began the process of preparing for hardware purchases for next year. As of June, we had successfully recruited two PhD students to work on the project. One of the PhD students started this fall in the Land and Atmospheric Sciences PhD program. Unfortunately, the other student ended up withdrawing in late August. We are planning to re-list this position for a Fall 2023 start.

Despite these challenges, Activity 2 remains on track with sensors being procured and deployed, data being collected, and models being developed.

Activity 3
We have successfully completed the planned trainings of farmers and local government units (SWCD's) in the use of the IMA tool and sensing systems. We have prepared and delivered three field days and reached ~150 people through these field days. Evaluation of these events showed that farmers are becoming more aware of the new irrigation technologies

(such as irrigation management assistant tool), have started showing interest and are considering adoption or changing some of their management practices based on the knowledge gained from these events. One main suggestion from these field days was to increase the length of the sessions. This next year we will continue to adapt our training and education plans to this information.

Dissemination

In addition to the extension and outreach activities described in activity 3, we have disseminated the results of our project through multiple popular and scientific venues. These include a blogpost on Irrigators Privacy in the Minnesota Crop News (https://blog-crop-news.extension.umn.edu/2022/08/protecting-privacy-of-irrigators-while.html), which was republished across multiple other agricultural news outlets such as agfax.com (https://www.agfax.com/2022/08/27/minnesota-irrigation-management-tool-update-protecting-privacy-while-providing-real-time-modeling/) and Farms.com (https://www.farms.com/news/irrigation-management-tool-update-protecting-irrigators-privacy-while-providing-real-time-modeling-183720.aspx).

Team members also shared project progress at multiple different presentations, including at the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) annual meeting, as well as three invited talks in the Departments of Horticultural Science, Computer Science and Engineering, and the Water Resources Center at the University of Minnesota. In addition to scientific presentations, we have draft publications overviewing the sensing system near submission to Computers and Electronics in Agriculture (Runck et al.). Additionally, the project team has regular meetings with SWCDs, MDA, growers, and UMN faculty.

Lastly, we had a profile piece of the project published in The Farmer by Paula Mohr

Status Update Reporting

Status Update June 1, 2022

Date Submitted: May 31, 2022

Date Approved: June 3, 2022

Overall Update
Since August of 2021, project 2021-266 has made consistent and considerable progress toward expanding the IMA tool into a 67-county application. Across the majority of our activity areas, we are ahead of schedule and have found cost savings. These savings have allowed us to devote more resources to data collection, which will improve the predictive abilities of the models in Activity 2. We have successfully navigated both staffing changes and supply chain challenges, two of the biggest management challenges nationwide right now. A few items of particular note include finishing the architecture design 5 months ahead of schedule, reducing the costs of extension programming to LCCMR by coordinating with other extension events, and the recruitment of high-quality PhD research assistants who will be able to achieve technical deliverables originally assigned to staff in Activity 2. In sum, we can report that we are on target to achieve all of our deliverables on time and within budget.

Activity 1
We are currently ahead of schedule on Activity 1. To date, we have successfully completed the architecture and interface design to make GEMS and RESPEC systems interoperable. Our architecture has preserved the privacy of irrigators while allowing for the exchange of supporting soils and weather data, and predictive analytics between the University of Minnesota and RESPEC servers. Our approach doesn't require any irrigator information to be shared outside of RESPEC's systems.

Because we completed the architecture earlier than expected, we have been able to make consistent progress on the scaled, limited release for 5 of the heavily irrigated counties and the integration of public datasets and weather data into the IMA tool. We anticipate this to be released ahead of schedule assuming no unforeseen delays. This progress has positive spillover effects into Activity 3 by allowing us to deliberately engage irrigators sooner in providing feedback on the user interface.

Activity 2
For activity 2, we are on schedule for all sub-activities with the exception of establishing 75 irrigation nodes in farmer fields, where we have been delayed by 3 months due to electronics supply chain challenges and unforeseen cost increases. To date, we have successfully finished 1) sensor design and manufacturing contracting with Caltronics of Stacy, Minnesota, 2) the negotiation and procurement of parts for sensor manufacturing, 3) the adaptation of real-time data systems for LCCMR sensors, 4) the establishment of field sites at Lamberton, Crookston, Becker, and Rosholt, 5) the generation of backup data collection efforts using Dynamax probes to accommodate the delayed delivery date of sensor nodes, and 6) the successful recruitment of PhD research assistants to staff research activities after other technical staff found higher-compensating positions. In sum, though we are currently delayed on the field deployment of sensors, we have identified backup data collection plans so that the overall outcomes of the project are currently unaffected.

Activity 3
We are on-track for all sub-activities and have delivered more than the 6 anticipated workshops over the past year. Specifically, we have delivered content on the IMA tool to approximately 670 irrigators, crop consultants, and SWCD professionals at 14 education and outreach events since August of 2021. In addition to these events, we have established a flagship engagement program through UMN Irrigation program called the "IMA Champions". This group consists of a dozen irrigators and conservation professionals who have agreed to provide detailed feedback on pre-release versions of the software system. The first meeting with this group was May 31, 2022.

In addition to these successes, the UMN Irrigation Extension program won additional funding for event hosting and content delivery. As a result, we have been able to defer costs associated with meetings by combining extension and outreach on the IMA tool with more general irrigation and conservation programming. These savings have allowed us to re-budget funds toward more data collection, instrumentation, and hardware.

Dissemination

Our primary mode of dissemination over the past year has been reaching over 600 people through regular and recurring meetings with irrigators and conservation professionals. Project team members have also engaged in regular meetings with the Minnesota Department of Agriculture, SWCDs, and individual irrigators to inform them of progress on the project and describe opportunities for engagement. All of these presentations have acknowledged ENRTF as the funder. These efforts will continue to scale across media platforms as the project begins generating results toward the end of this calendar year.