Crop and Water Monitoring Networks with Low-Cost, Internet Of Things Technology

Ansley Brown, Emmanuel Deleon, Erik Wardle

Department of Soil and Crop Sciences, Colorado State University, 1170 Campus Delivery, Fort Collins, Colorado, USA

A paper from the Proceedings of the
16th International Conference on Precision Agriculture
21-24 July 2024
Manhattan, Kansas, United States

Abstract.
Making meaningful changes in agroecosystems often requires the ability to monitor many environmental parameters to accurately identify potential areas for improvement in water quality and crop production. Increasingly, research questions are requiring larger and larger monitoring networks to draw applicable insights for both researchers and producers. However, acquiring enough sensors to address a particular research question is often cost-prohibitive, making it harder to draw meaningful conclusions from data collection. Even if enough sensors can be acquired, data can often not flow freely between sensor manufacturer data platforms, adding to the time and labor costs associated with data analysis and delivery. This can also prohibit real-time data access, which is critical to subsequent decision-making (e.g., deciding whether to apply fungicide to a sugar beet crop). To help address these concerns, the Colorado State University Agricultural Water Quality Program (AWQP) has developed low-cost, edge-of-field (EoF) and crop health monitoring systems with Internet of Things (IoT) technology for scalable, near-real-time research. For EoF monitoring, the AWQP developed an open-source, automated water sampler that can detect flow depth and sample water remotely for approximately 1/10th of the cost of an equivalent commercial model. The sampler was deployed in 6 research locations across Colorado in 2023. For crop health monitoring purposes, the AWQP worked with commodity group, Western Sugar, to develop a temperature and humidity sensor capable of estimating Cercospora leaf spot infection risk for optimized fungicide applications. After harvest, this same device can interchange sensors to become a sugar beet storage pile temperature monitor. All developed sensors have been compared to commercial/existing methods for monitoring with the intention of making an open-source product, and results will be discussed.

Keywords.
Water quality, IoT, low-cost technology, sugar beet, decision support system

Introduction

In Colorado and across the United States, agriculture is being identified as one source of nutrient pollution in State and Federal waters. Nutrients such as nitrogen and phosphorus run off farmlands and accumulate in surface waterways, causing water quality issues. Starting in 2012, Colorado Regulation 85 (5 CCR 1002-85) began more stringent regulation of "point source" nutrient dischargers, such as wastewater treatment plants. Agricultural nonpoint sources are discussed in the regulation, but mandatory requirements are currently not implemented. Instead, nonpoint sources are encouraged to adopt practices that can help reduce nutrient pollution in surface waterways.

The Colorado State University (CSU) Agricultural Water Quality Program (AWQP) protects Colorado state waters and the environment from impairment or degradation due to the improper use of agricultural chemicals while allowing for their proper and correct use. In partial fulfilment of this mission, the CSU AWQP has been developing low-cost, internet of things (IoT) technologies to aid in environmental monitoring in a scalable, near-real-time manner that facilitates improved decision-making by various water stakeholders.

Two notable projects underway include 1) a low-cost, IoT automated water sampler (henceforth, LCS), and 2) an IoT sugar beet crop health monitoring system.

Materials and Methods

Low-Cost, IoT Automated Water Sampler

Voluntary edge-of-field (EoF) monitoring is the most direct way to evaluate agriculture's impact on pollutant runoff in agricultural systems. Unfortunately, existing research-grade technology available for EoF monitoring is prohibitively expensive and impractical for widespread deployment, especially in semi-arid regions where runoff events from precipitation are infrequent.

To address this need, the CSU AWQP developed the LCS to perform EoF monitoring in a scalable manner. The LCS detects water presence, measures water depth, and collects water samples for later pickup. It does so entirely through remote connection with the user and is approximately $1/10^{th}$ the cost of a commercial equivalent used for EoF monitoring.

In 2023, the LCS was deployed at 6 locations across Colorado at producer and experimental sites and deployed against commercial standard and manual grab methods for a robust comparison study.

IoT Sugar Beet Crop Health Monitoring System

In sugar beet production, two main operations have been identified by the CSU AWQP, in collaboration with Western Sugar (WS) and University of Nebraska-Lincoln (UNL) as an opportunity to capitalize on integrating low-cost, Internet of Things (IoT) sensing into the sugar production process: 1) detecting sugar beet susceptibility to cercospora leaf spot (CLS), a common and detrimental leaf pest, and 2) detecting sugar loss in post-harvest sugar beet piles with temperature sensors.

In 2021, 2022, 2023, and 2024 the CSU AWQP prototyped and deployed 90 temperature (T) and relative humidity (RH) sensors that stream data to determine daily infection values (DIVs) that are displayed on a real-time webpage to provides CLS risk to WS agronomists and producers. In 2022 and 2023, a sub sample of sensors were placed next to existing, commercial sensors for a side-by-side comparison study that spanned CO, WY, NE, and MT.

Results and Discussion

Low-Cost, IoT Automated Water Sampler

Results of comparisons made between the LCS, the commercial standard sampler, and handheld bottle collection methods indicate that all methods perform similarly for water quality analysis, yielding no statistically significant differences among all tested analytes (Kruskal-Wallis rank sum test, $p = 0.9236$, $n=1187$). *Analytes tested include Ammonium Nitrogen (EPA 350.1), Nitrate-Nitrite (EPA353.2), Total Phosphorus (EPA365.2), Total Kjeldahl Nitrogen (A4500-NH3), Orthophosphate as P (EPA300), and Total Suspended Solids (EPA160.2). Additionally, the AWQP will add the following tests: Total Dissolved Solids (EPA 160.1), specific conductance (EPA 120.1), and pH (EPA 150.1).* The LCS continues to be used by CSU AWQP staff to monitor EoF sites around the state of CO for scalable monitoring of water quality in various agricultural systems across the state.

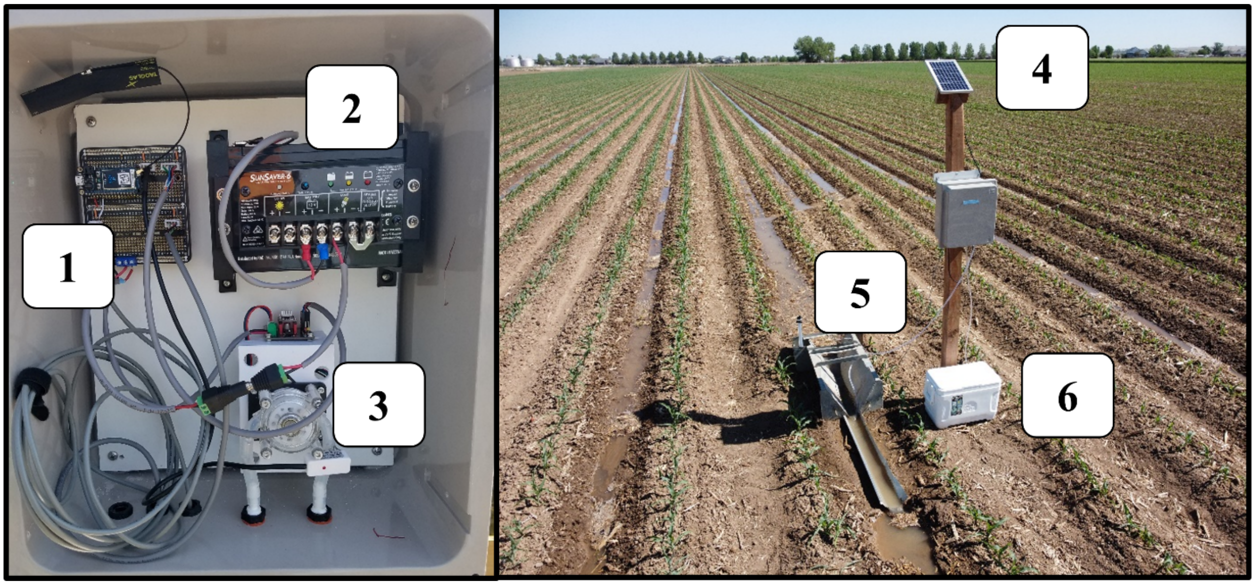

Figure 1. Picture of the low-cost automated water sampler (LCS) deployed in-situ, with its primary components annotated: 1) a cellular-enabled microcontroller, 2) a 12 V battery and solar charger, 3) a peristaltic pump with tubing, 4) a 12 V, 10 W solar panel, 5) a water depth detecting sensor, and 6) a cooler for preserving samples.

IoT Sugar Beet Crop Health Monitoring System

Results from all study years indicate that the sensors perform adequately to such that they could be a reasonable substitute for current methods of monitoring CLS and storage pile temperature (PT). In 2022, CSU and commercial sensors had more similarity in T readings than in RH, with average Root Mean Squared Error (RMSE) values of +/- 3.43 °F and +/- 7.36 %, respectively over all compared sensors. RMSE in 2023 was very similar to average T and RH% RMSE values at +/- 3.0 °F and +/- 7.7 %, respectively. These accuracies were deemed sufficiently accurate for WS staff, especially given that the additional benefit is near-real-time decision-making.

Furthermore, AWQP staff hosted hybrid training sessions with 16 WS agronomists to instruct them on sensor assembly and deployment. This allowed for a more scalable solution without the need for 3rd party contractors, which would incur undue costs for the simplicity of the device.

Conclusion

Both environmental systems are active, useful, and will ultimately become open source products for future development and easy sharing. To learn more, visit https://waterquality.colostate.edu.