

Project Name: Quantifying Nitrogen Leaching in Irrigated Fields

Principal Investigator and Cooperators: Dr. Adam Sigler; Dr. Clain Jones; Mitch Konen; Bill Lee; Travis Stuber (Travis was added as an additional Gallatin cooperator after initial proposal)

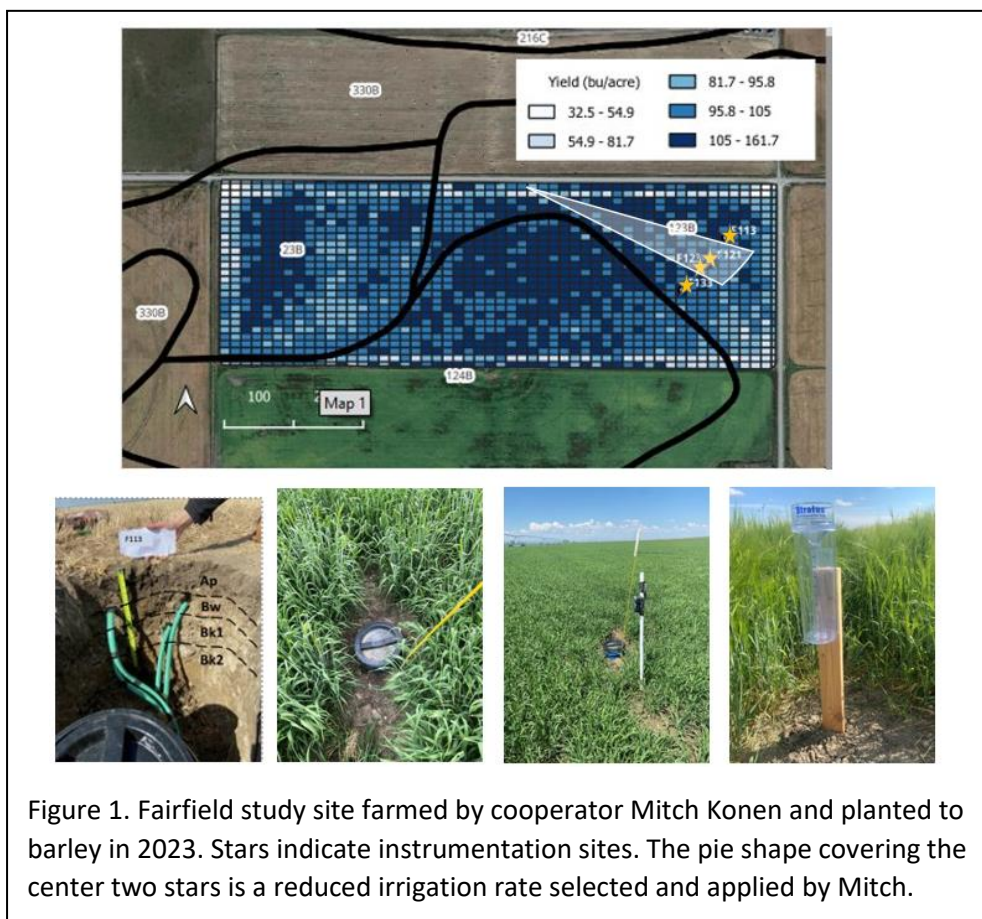
Time Period: July 1, 2023 - June 30, 2024

Project Results:

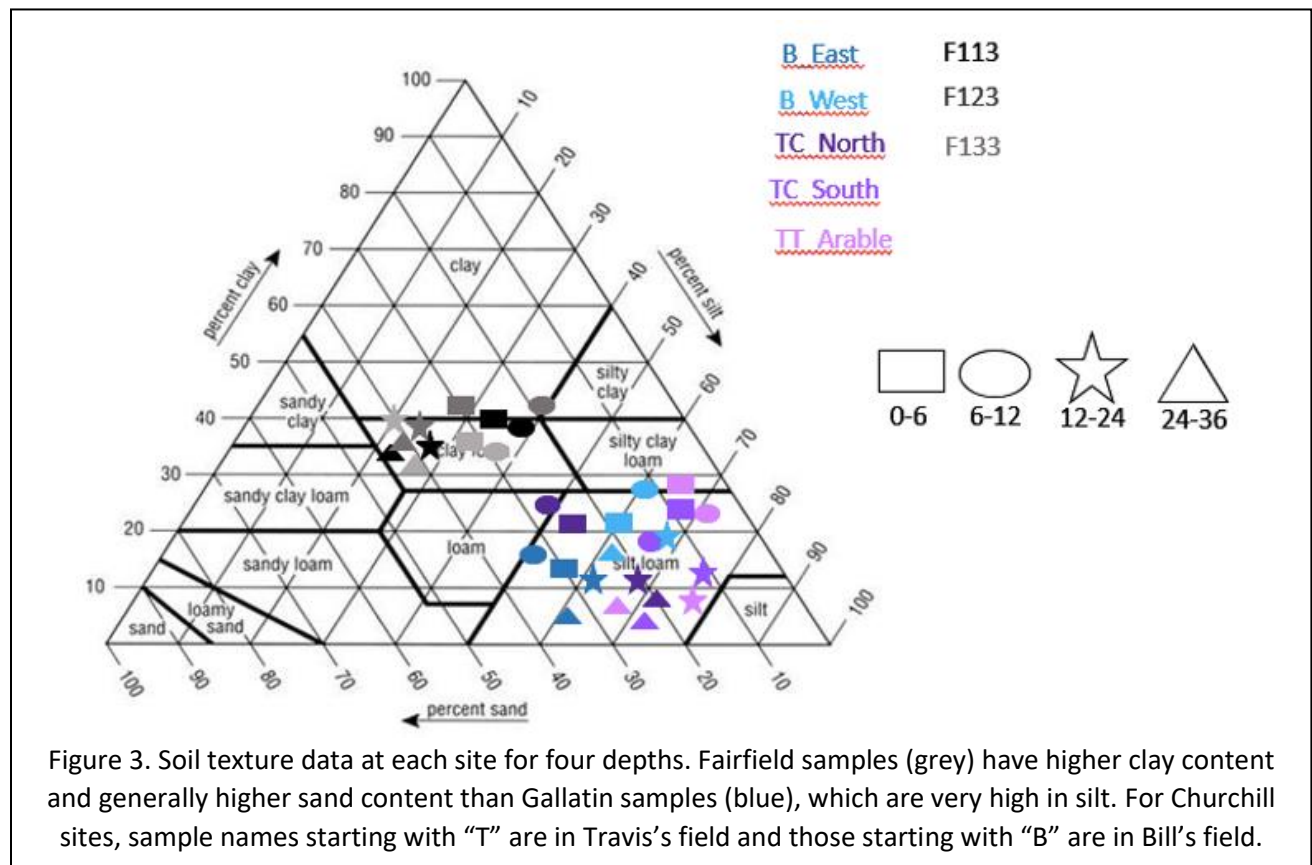
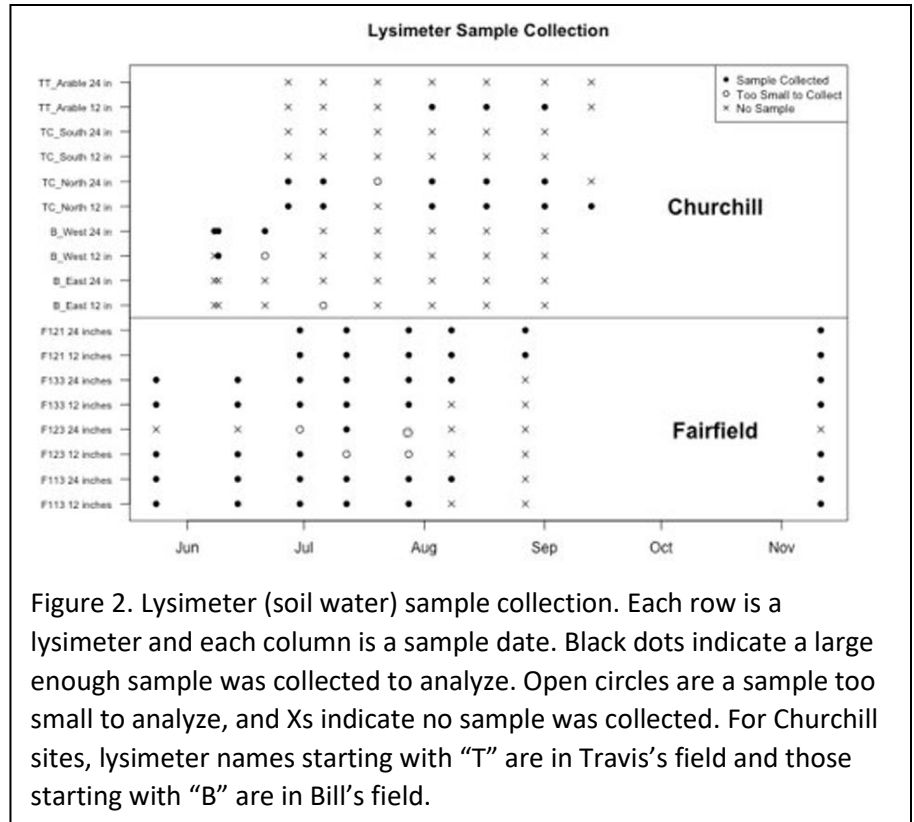
Field instrumentation and sampling: During spring/summer 2023, we instrumented four soil pits in cooperator Mitch Konen's field near Fairfield under barley (Figure 1), and five additional sites in the Gallatin under seed potatoes, in fields farmed by Bill Lee (two instrumented pits) and Travis Stuber (three instrumented pits). Each soil pit included soil moisture sensors at three depths (6", 12", 36") and lysimeters (soil water samplers) at two depths (12" and 24"). We also installed

an Arable Mark 3 weather station in Mitch Konen's field that uploaded real time data to the web for soil moisture and weather data, which was available to us and to the producer in real time. We worked in partnership with MSU precision agriculture cooperating researchers to have parallel Arable instrumentation in the two Gallatin potato fields, with data available to cooperators.

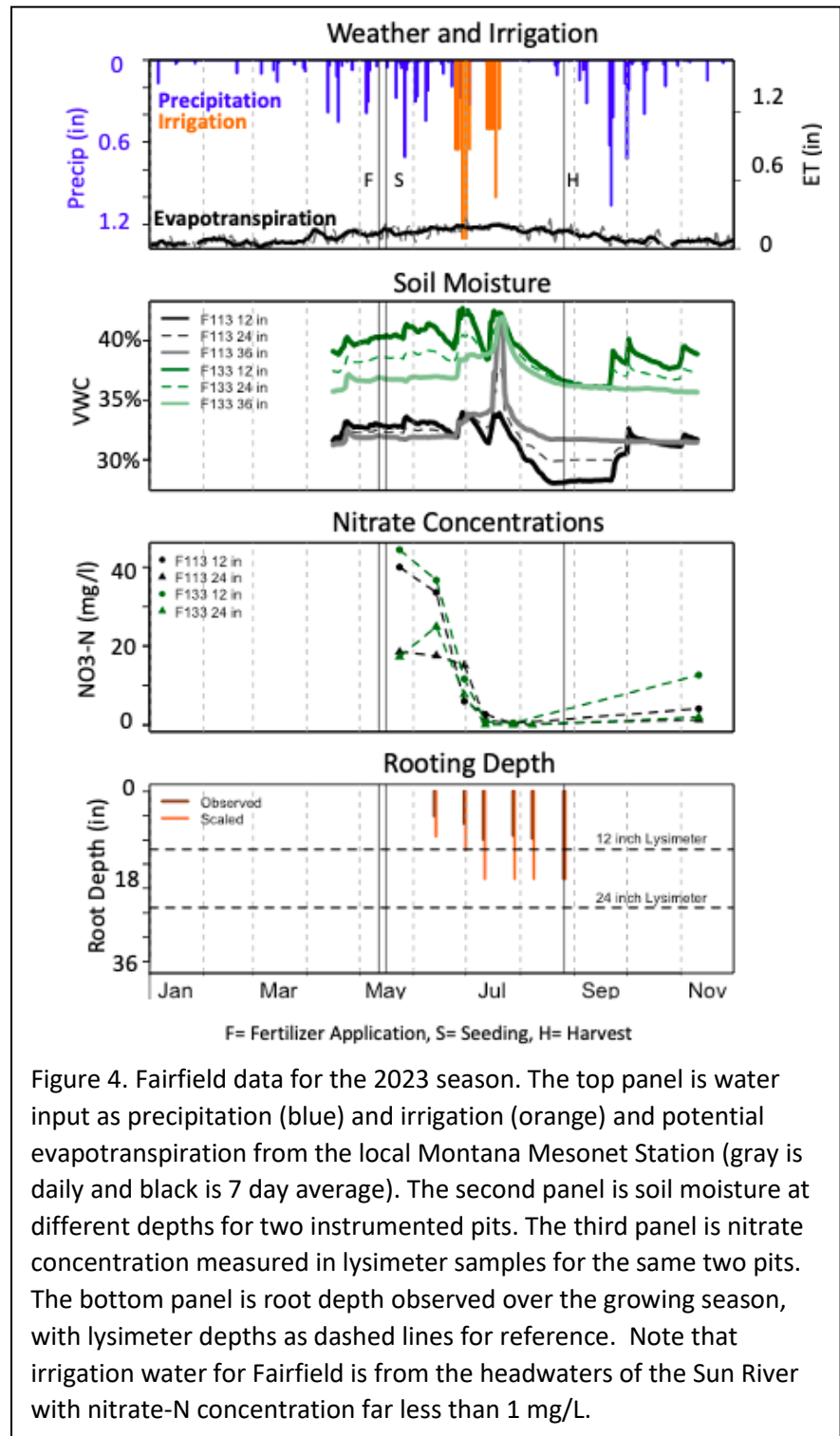
Graduate student Meghan Robinson and a field technician visited each instrumented pit every two weeks to download soil moisture data and place the lysimeters under vacuum to collect soil water samples over a 24-hour period. Soil samples were collected at the beginning of the season and analyzed for nutrient concentrations and soil texture. Observations of rooting depth were collected during each field visit.



Preliminary results: A total of 59 lysimeter samples were collected, with a significantly higher number of samples collected in Fairfield (42 samples) than in the Gallatin (17 samples), despite having more instruments in the Gallatin than in Fairfield. Higher clay content in soils at the Fairfield study site versus higher silt at the Gallatin sites (Figure 3) are believed to be the primary explanation for the far lower number of lysimeter samples collected in the Gallatin (Wiehermuller et al., 2007).



Preliminary results indicate nitrate-N concentrations at the Fairfield site starting around 40 mg/L in the shallow lysimeters and dropping to concentrations near zero by mid-July (note that irrigation water at this site is from the headwaters of the Sun River with nitrate-N concentration less than 1 mg/L). The period of this drop in concentration is concurrent with a period of increased soil moisture at the onset of irrigation that likely caused deep percolation of water out of the root zone. Rooting depth was between 5 and 10 inches at the start of June and was between 9 and 18 inches by mid-July. Roots reached the depth of the shallow lysimeters around June 30th, so it is likely that most of the decrease in nitrate concentration in the 12" lysimeters between June 30th and July 15th is due to crop uptake. In contrast, rooting depth apparently never reached the 24" lysimeters, because rooting depth observed immediately after harvest (August 26th) was only 18 inches. Presence of nitrate-N at the deeper lysimeter (ranging up to 25 mg/L and below max rooting depth) during periods of deep percolation, suggests that leaching of nitrate is at least a partial explanation of the drop in nitrate concentrations and that some nitrogen was lost from the root zone before the crop roots could access it. Detailed analysis focused on this critical period between mid-June and mid-July is ongoing. This period of deep percolation during the growing season differs from findings in a dryland system, where most deep percolation occurred earlier in the spring



and in years following fallow (Sigler et al., 2020). The current evidence for deep percolation and nitrate leaching during the growing season may therefore have implications for irrigation management that could attempt to limit losses. Analysis of the more limited set of lysimeter samples from the Gallatin shows a similar trend of decreasing nitrate concentrations over the course of the growing season, however we observed more limited responses in soil moisture at our 36" sensors. This suggests irrigation water was not reaching deeper soils in the Gallatin as readily as in Fairfield, and that leaching risk may be lower in the Gallatin. We are exploring soil texture/structure as explanations for these differences between sites. Notably, large pores that don't collapse are more likely in Fairfield's clays, facilitating downward water movement.

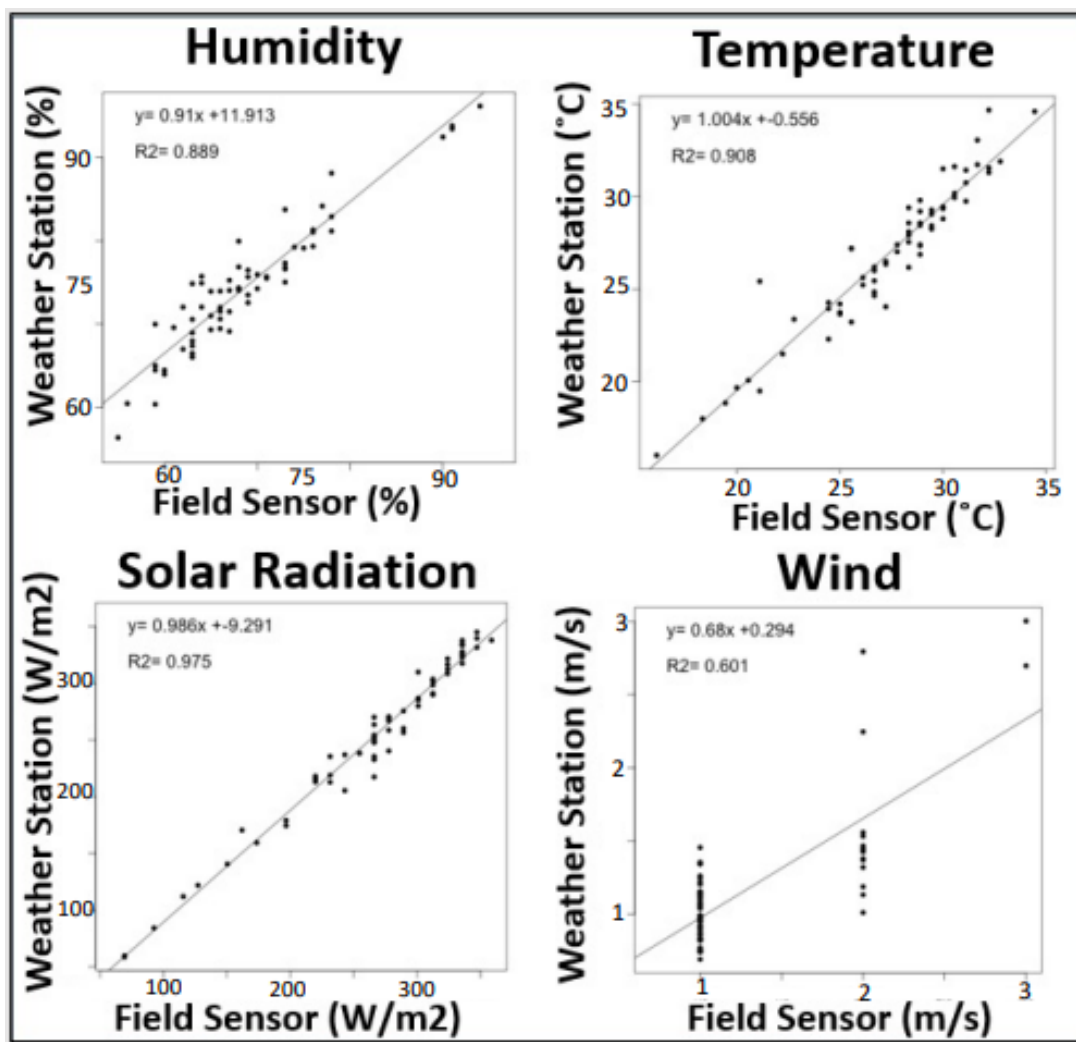


Figure 5. Regressions comparing observations collected by Arable weather stations deployed at a Gallatin study site versus a Montana Mesonet station approximately 2 miles away. Not pictured here are precipitation data comparisons, which include differences from spatial weather patterns as well as possible sensor reliability issues with the acoustic based precipitation sensor on the Arable unit (i.e. it measures rain based on the sound it makes hitting the top of the unit).

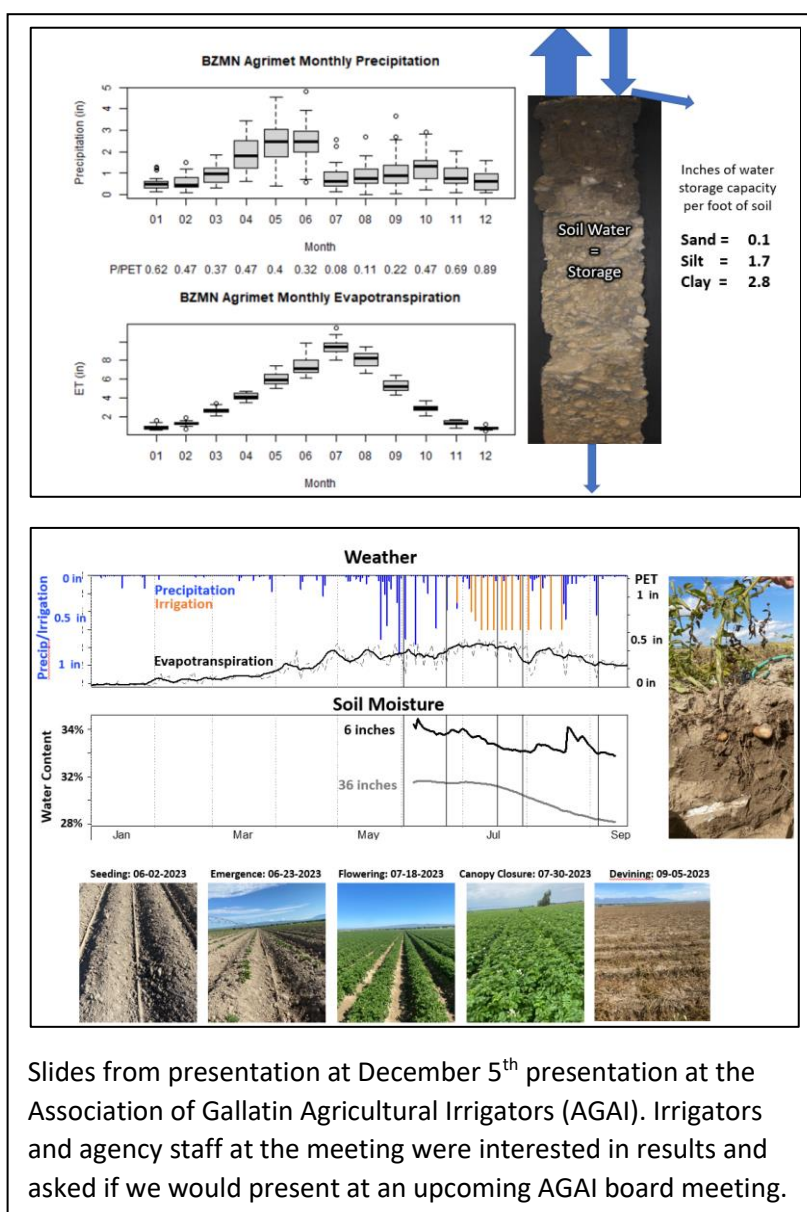
We are relying on model results, informed by soil moisture observations, to quantify the amount of water lost from the root zone (deep percolation) and we are still refining our model calibration. One issue with our model calibration is lack of knowledge about actual evapotranspiration from the fields, compared to the potential evapotranspiration we get from weather stations. For 2024, we will propose to purchase some exciting new instruments (LICOR 710) that allow for the direct measurement of actual ET at field sites. These instruments have a cost (~\$6,000), approximately 10 times lower than the current comparable measurement approach that uses Eddy Covariance towers.

We have also been comparing results from different sensors to determine sensor reliability and which measurements need to be made at study fields versus measurements that can be used from local Montana Mesonet stations (Figure 5). We expect weather parameters such as relative humidity, temperature, solar radiation, and wind to be reasonably consistent over spaces of a few miles. Precipitation can vary more extensively over short distances and soil moisture must be measured in situ in irrigated fields to be meaningful for management.

Outcomes:

We were invited and presented preliminary research results to participants in the Headwaters Leadership Summit, hosted by the Montana Chamber of Commerce, on September 28th.

We also presented our end of season results to cooperators Bill Lee and Mitch Konen in one-on-one meetings to solicit their feedback. We were invited and presented preliminary results at the annual meeting of the Association of Gallatin Agricultural Irrigators (AGAI; see slides at right), and were invited to give an early overview of the project goals at a Sun River Watershed Group annual water quality meeting during the summer of 2023 as well.



Slides from presentation at December 5th presentation at the Association of Gallatin Agricultural Irrigators (AGAI). Irrigators and agency staff at the meeting were interested in results and asked if we would present at an upcoming AGAI board meeting.

Impacts:

Since we are only 6 months into the funding period, we have limited impacts to report. However, in addition to our cooperating producers, several other agency and agricultural producers have reached out to request more information about our results including NRCS staff and the board of the Association of Gallatin Agricultural Irrigators. The interest from producers outside of our cooperators is particularly interesting given the estimate that only 5% of Montana producers currently use soil moisture data in their irrigation decision making (USDA, 2018). A review of past nitrate leaching research identified more precise water management in irrigated systems as a beneficial method for limiting nitrate leaching losses without compromising crop yields, as opposed to reduced fertilizer rates which could be detrimental to yields (Quemada et al. 2013). For this reason, we are optimistic that the interest we have received from producers and agency staff may translate into action as we continue our research and refine our understanding of irrigation management opportunities to improve water and nitrogen use efficiency.

References:

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