Soil Texture and Seasonal Changes in Soil Structure Control Deep Percolation and Nitrate Leaching Risk in an Irrigated System

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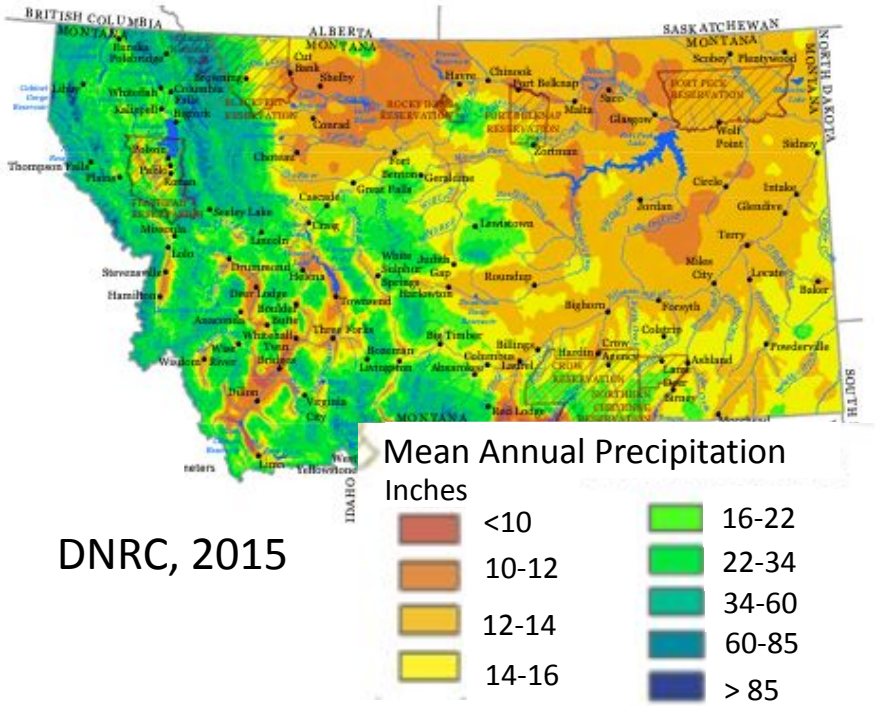
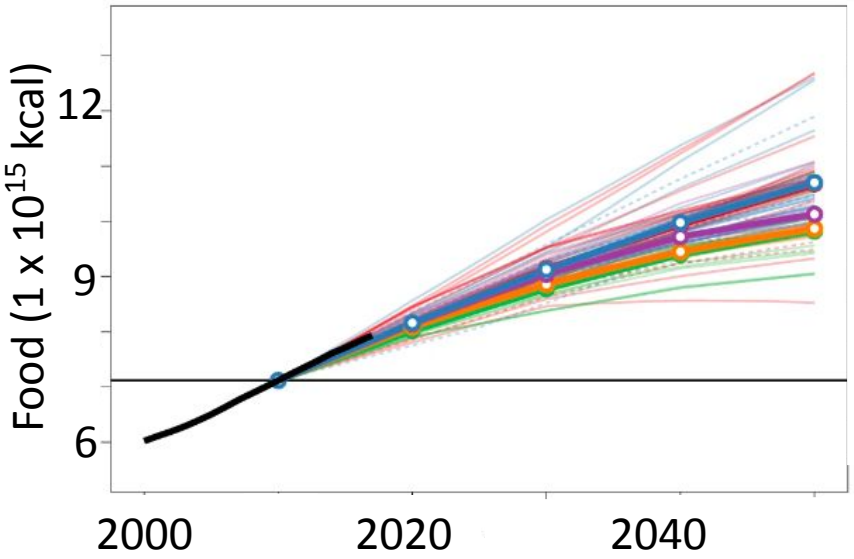
Water in Agriculture



DNRC, 2015

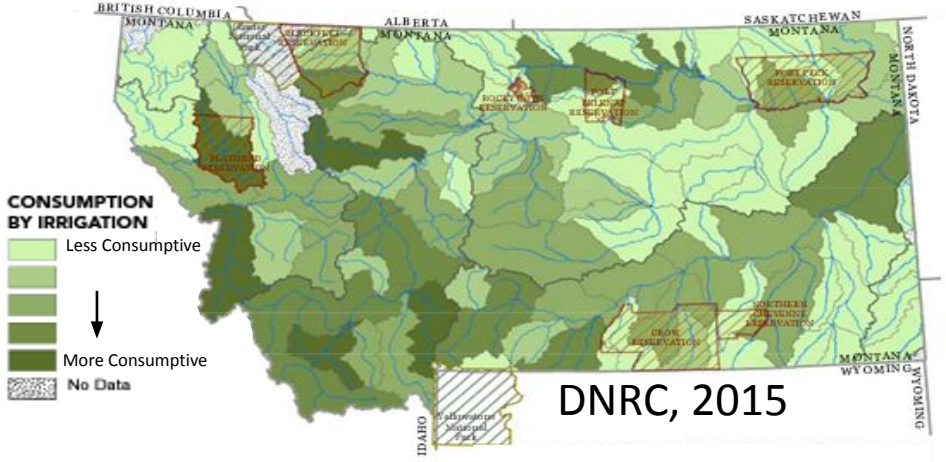
Water limits food production in semi-arid areas, and there is increasing uncertainty around water supply

Global Food Demands



Van Dijk et al., 2021

In MT, 70% of consumptive water use is for irrigation

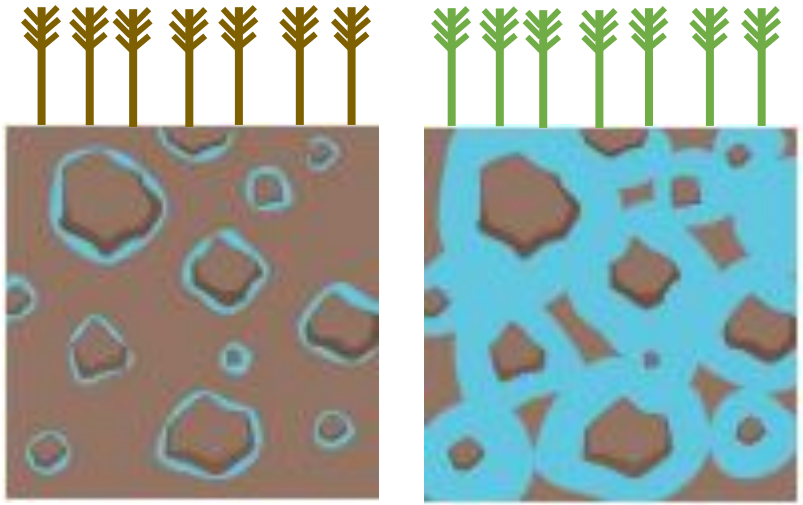


DNRC, 2015

Irrigated areas account for 17% of cultivated land, but 40% of global food supply

Soil Moisture Management

Soil water holding capacity:
controlled by thickness and texture



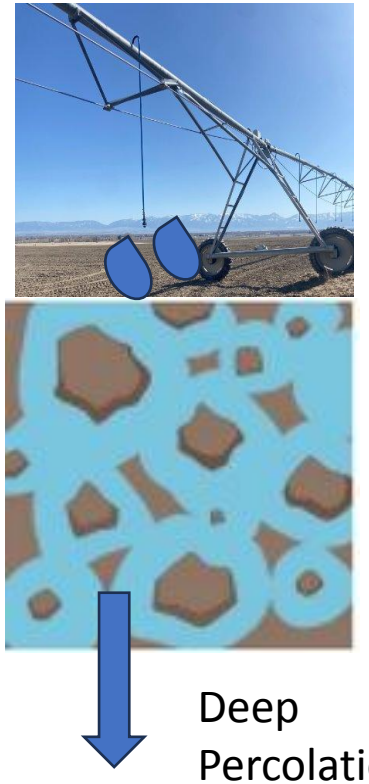
Wilting Point

Field Capacity

Water Storage:

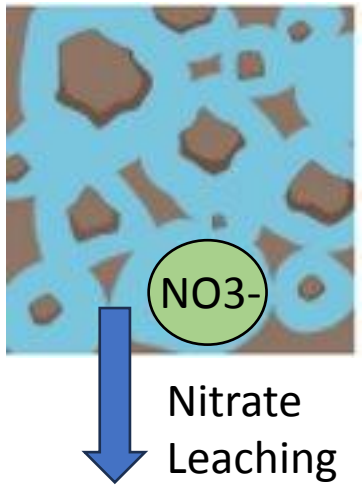
Sandy loam: 1.7 inches per foot
Silty loam: 1.9 inches per foot
Clay loam: 2.4 inches per foot

Management Opportunities:

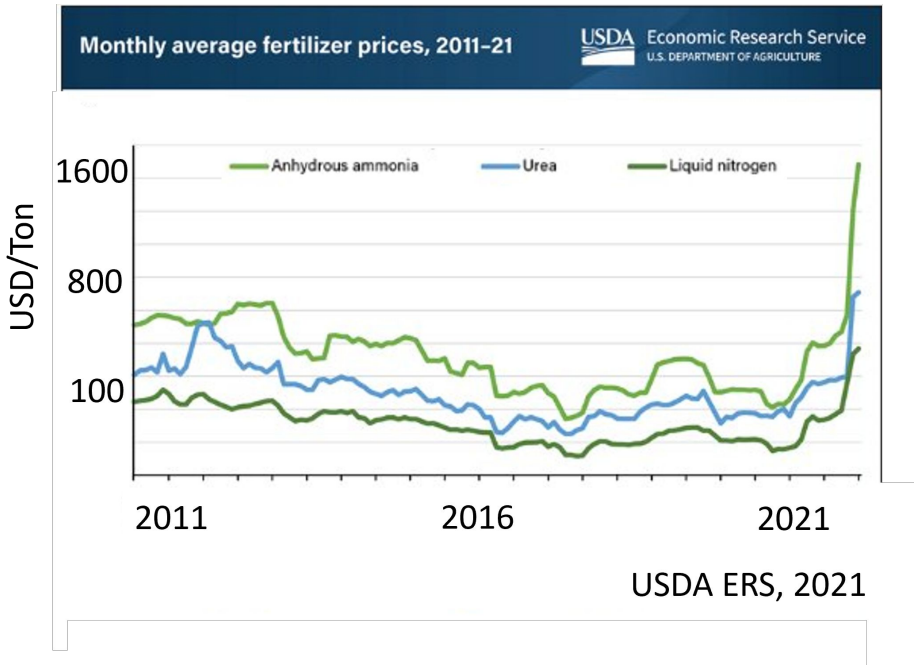


Deep
Percolation

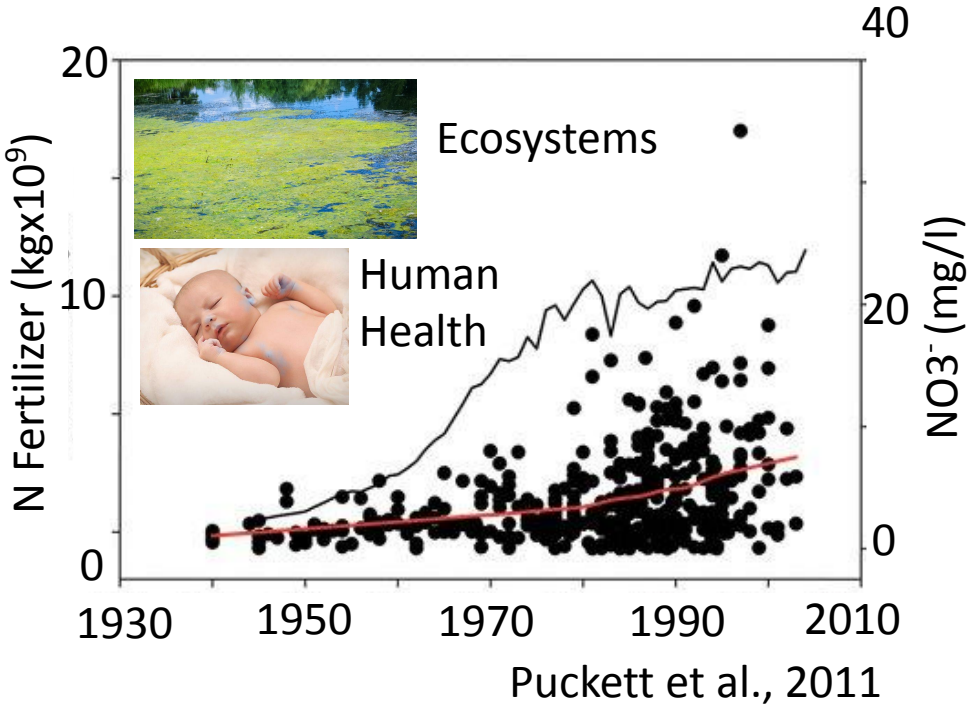
Nutrient Loss Challenges



Economic Challenges



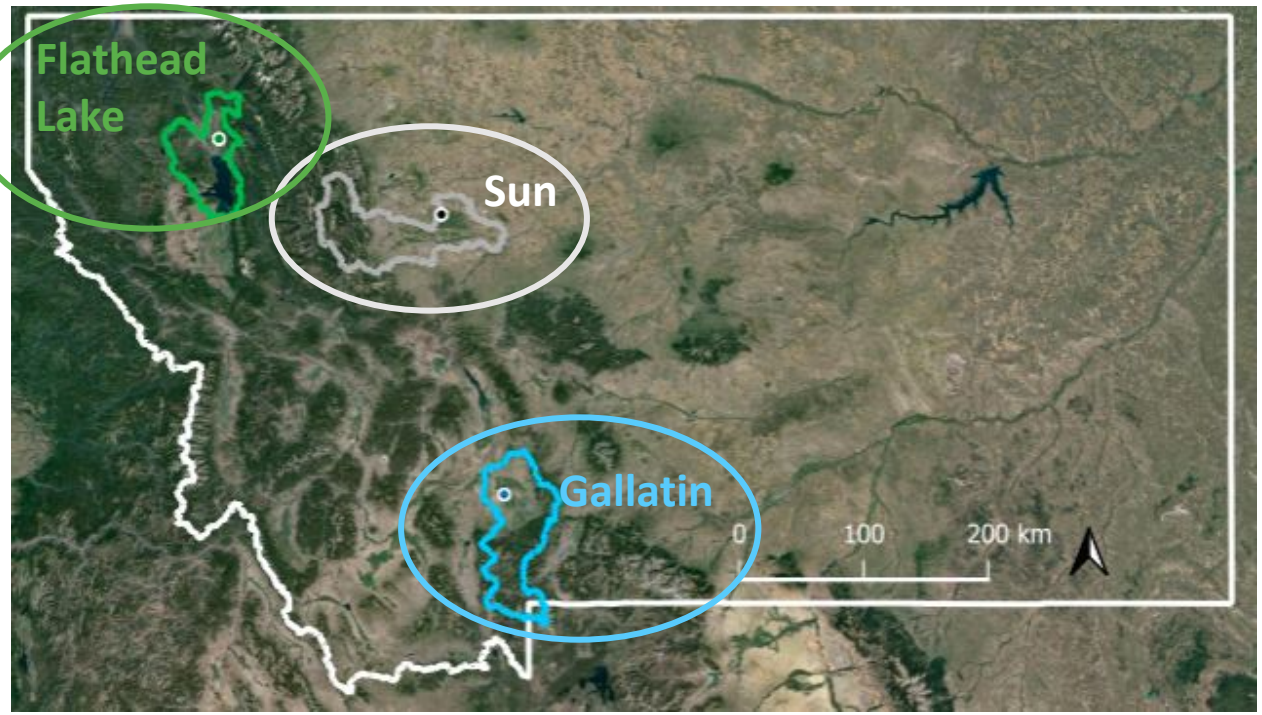
Water Quality Challenges



Research Question

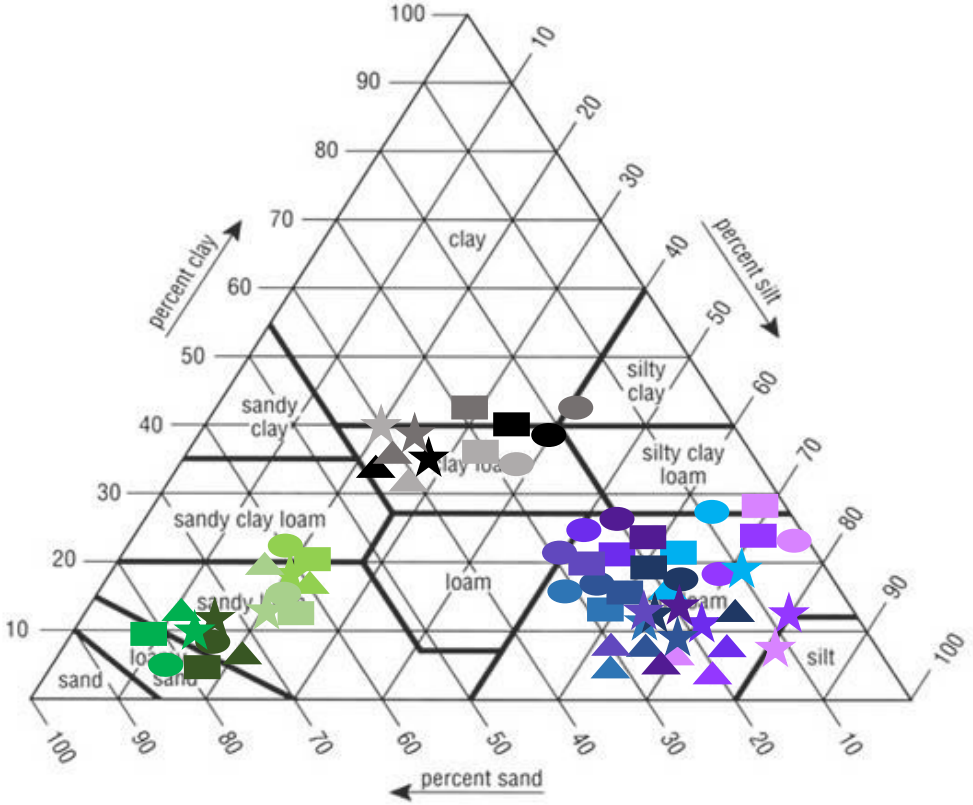
How do **weather, soils, and irrigation management decisions** interact to impact **water and nutrient losses** to deep percolation and runoff?

Study Locations



Fairfield:

- Sun River Watershed
- Clay Loam- ~35% clay
- Barley and spring wheat



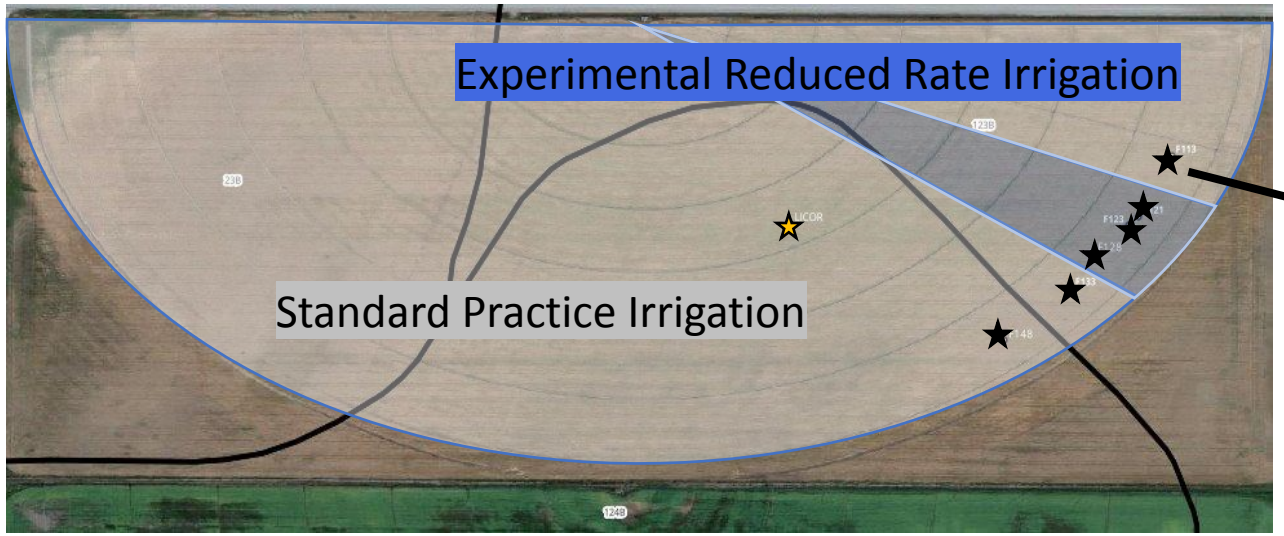
Creston:

- Flathead Lake Watershed
- Sandy Loam- ~70% sand
- Spring wheat

Churchill:

- Gallatin River Watershed
- Silty Loam- ~70% silt
- Potatoes

Field Instrumentation



Soil Moisture Sensor — 6 inches

Soil Moisture Sensor
Lysimeter — 12 inches

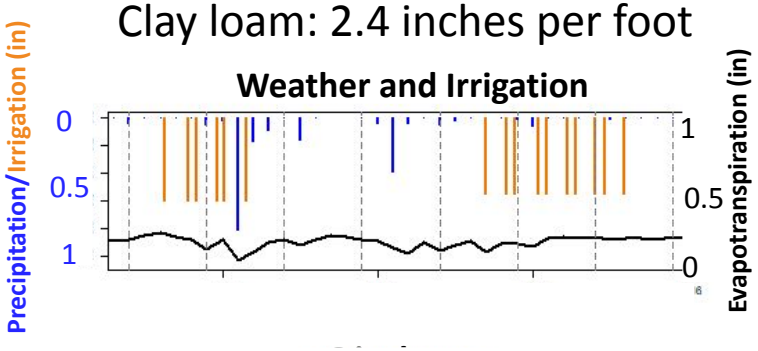
Soil Moisture Sensor
Lysimeter — 24 inches

Soil Moisture Sensor — 36 inches

Moisture Responses Across Soils

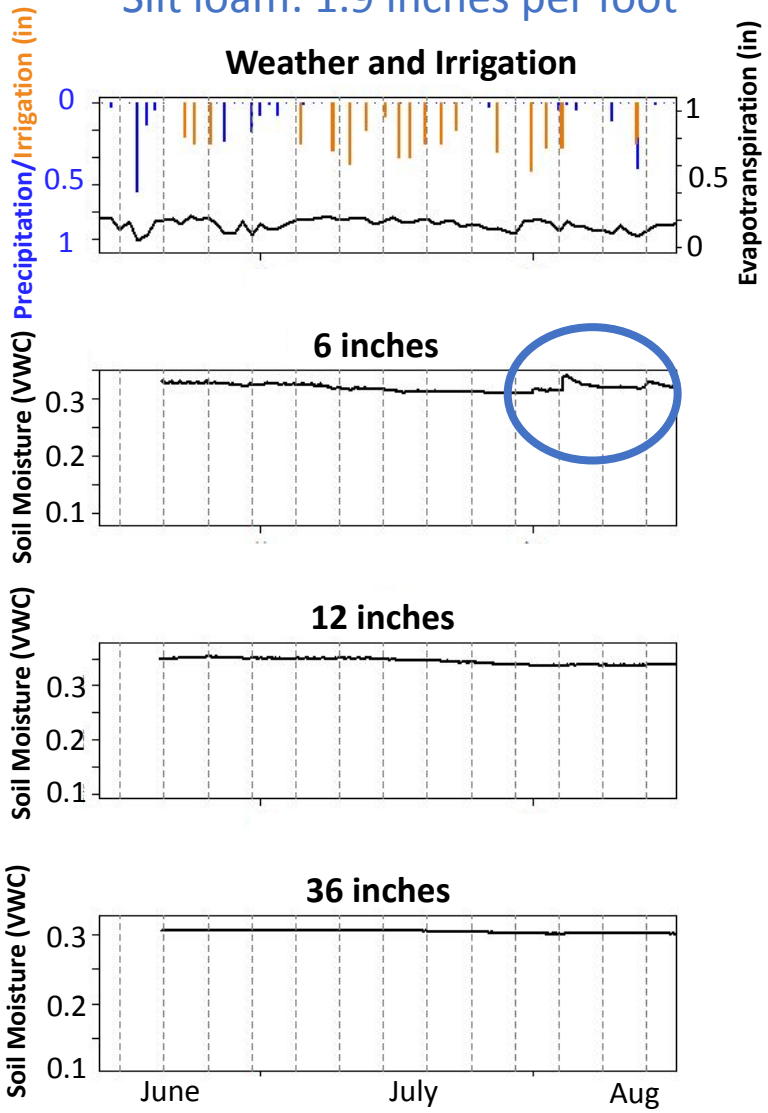
Fairfield

Clay loam: 2.4 inches per foot



Churchill

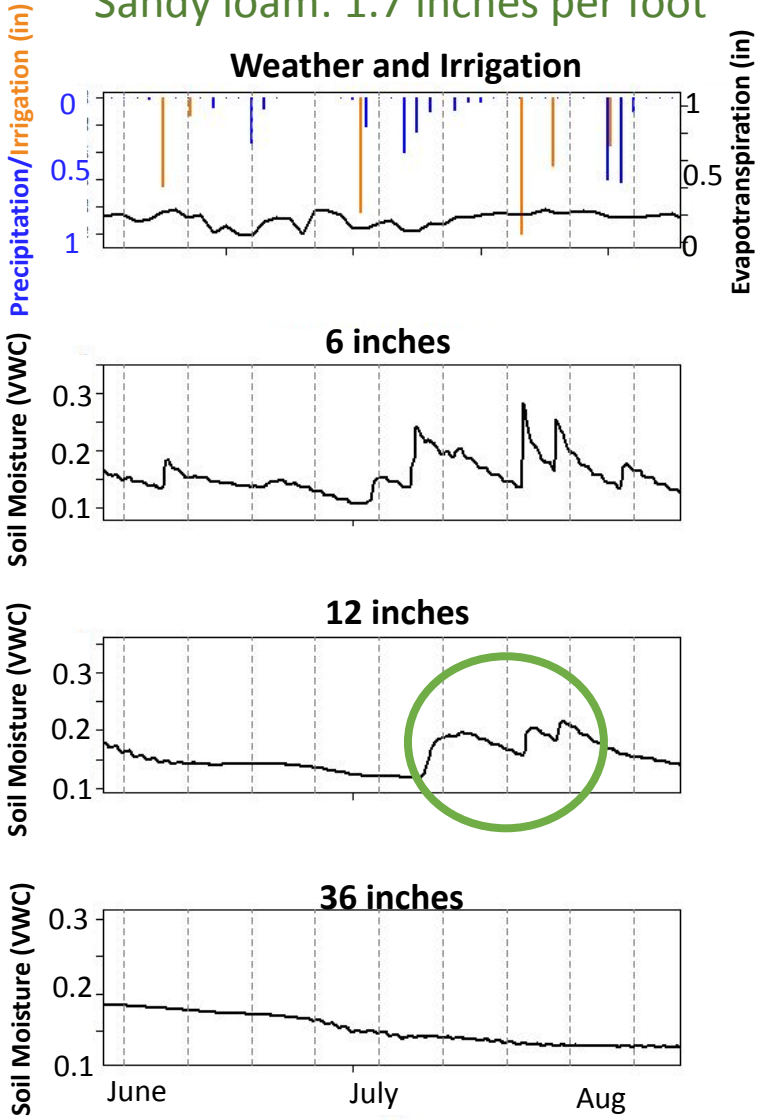
Silt loam: 1.9 inches per foot



*Different sensors used in Gallatin- relative magnitude comparable, values are high

Creston

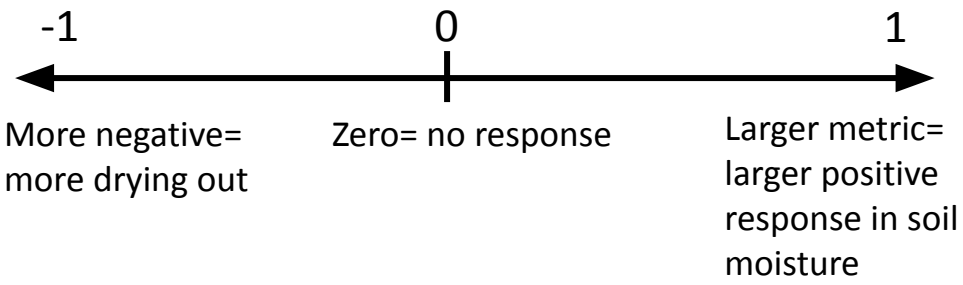
Sandy loam: 1.7 inches per foot



Soil Moisture Metric

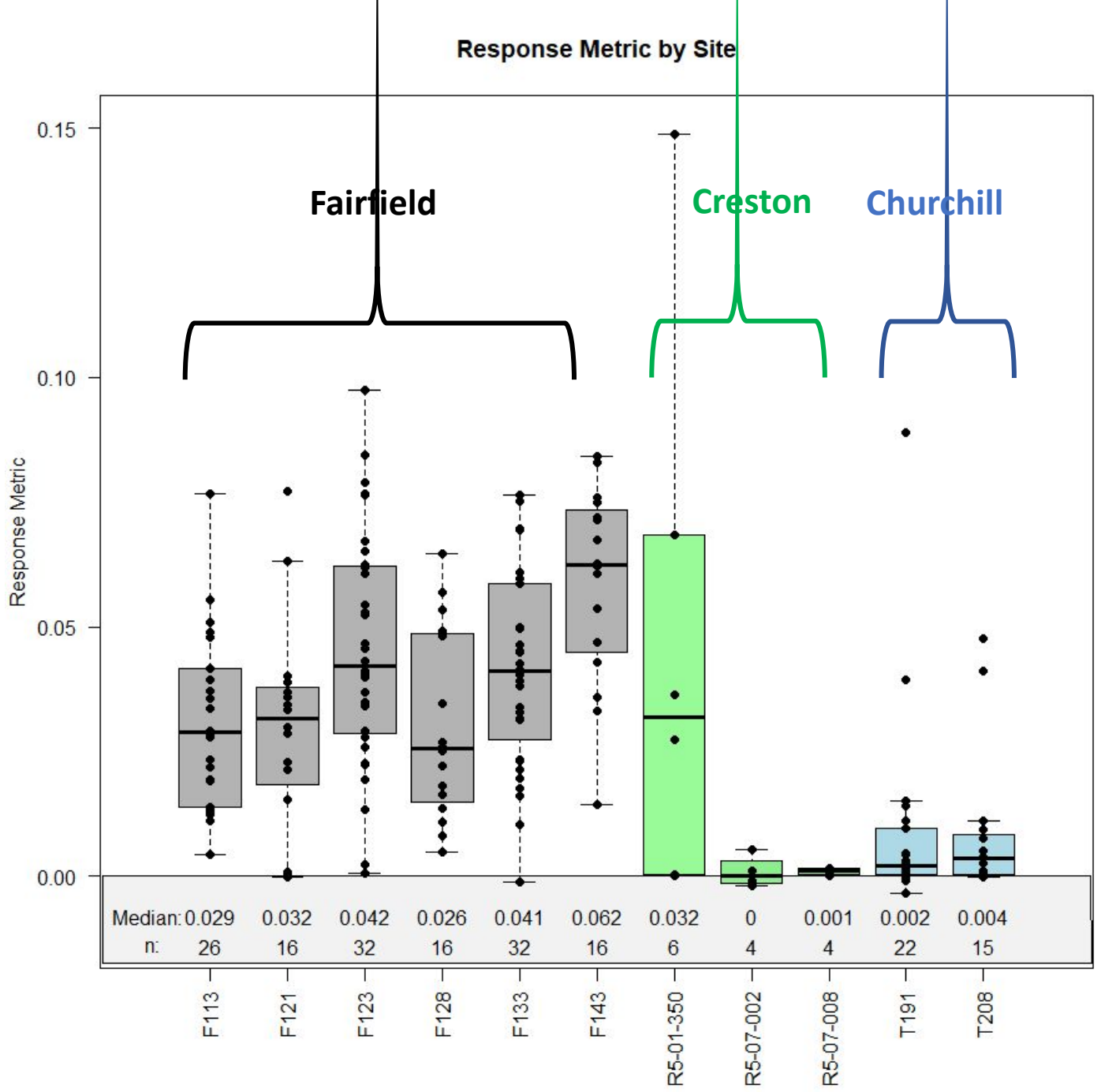
$$\text{Response Metric} = \frac{\overset{2}{\text{Peak 6 in Soil Moisture (VWC)}} - \overset{1}{\text{Initial 6 in Soil Moisture (VWC)}}}{\underset{3}{\text{Irrigation}} + \underset{4}{\text{Precipitation}} - \underset{5}{\text{Evapotranspiraton}}}$$

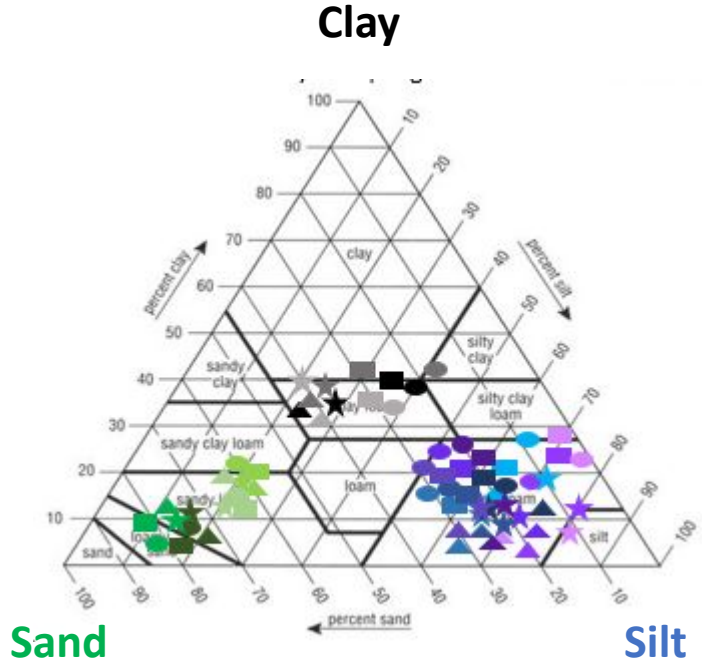
Only calculated for **irrigation** events so far!



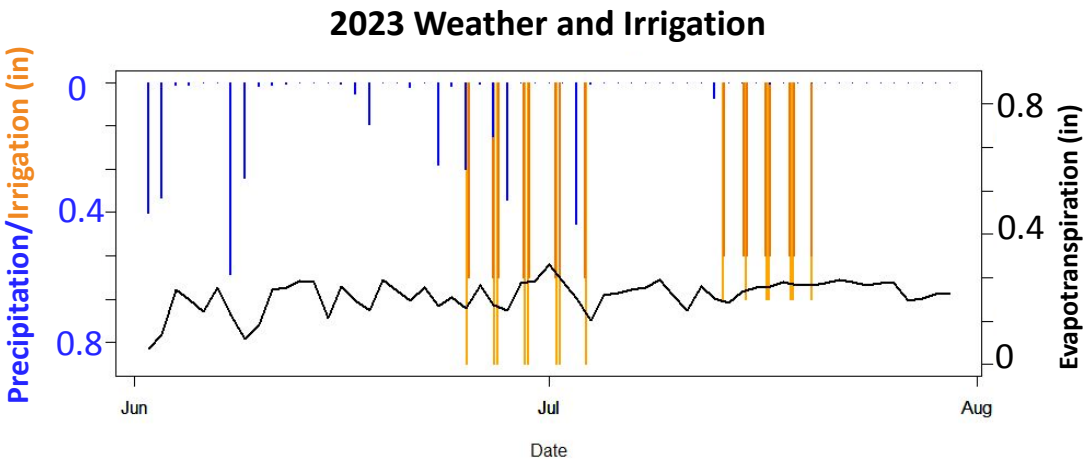
Larger positive response

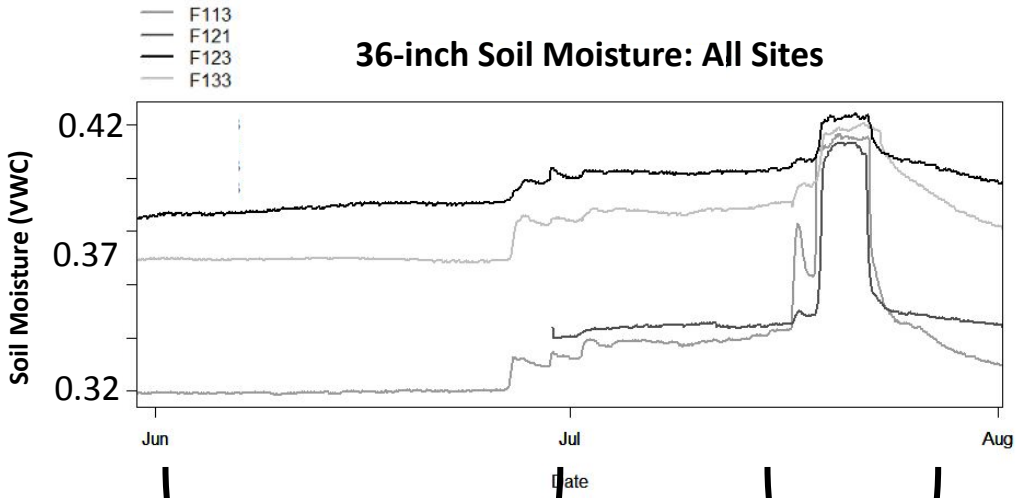
More Intense Drying





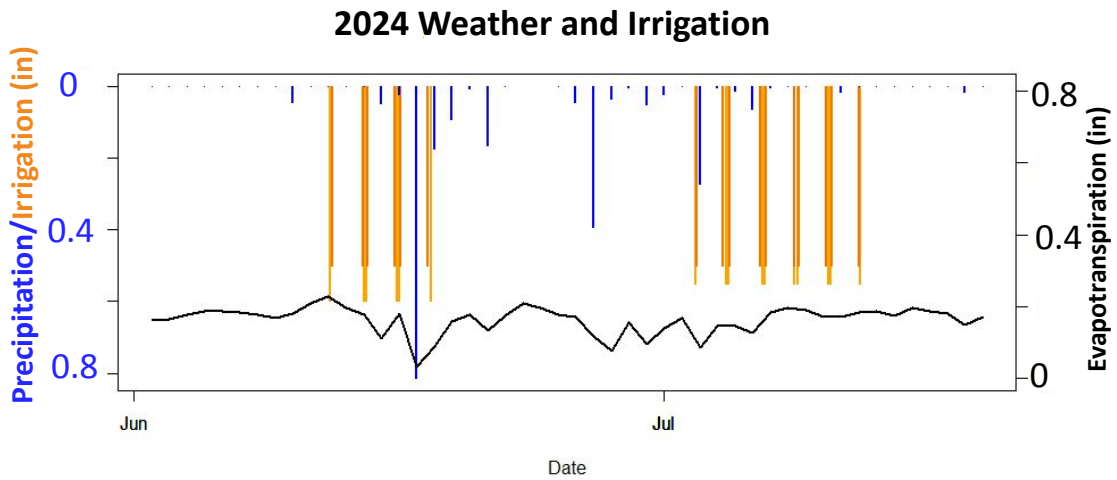
Linking to Deeper Responses

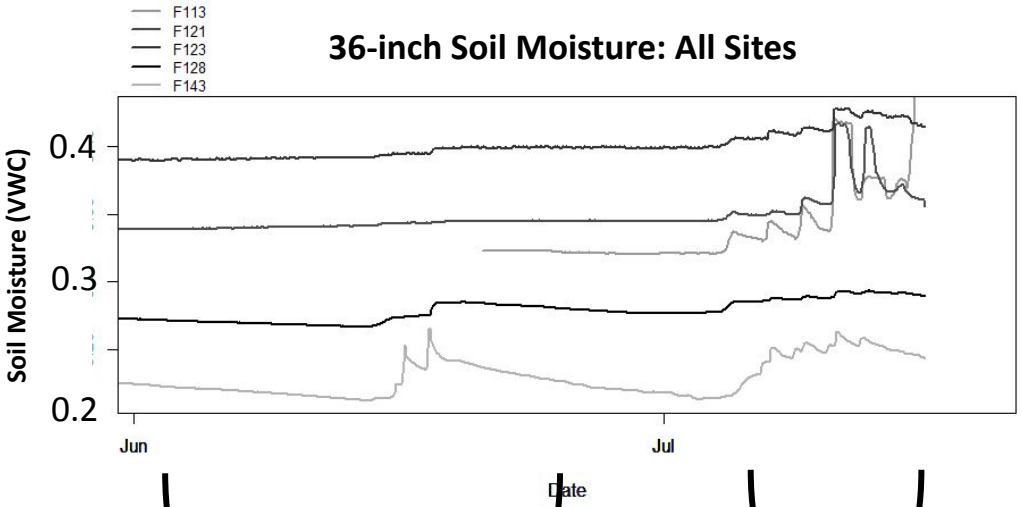




Low Responsiveness

High Responsiveness

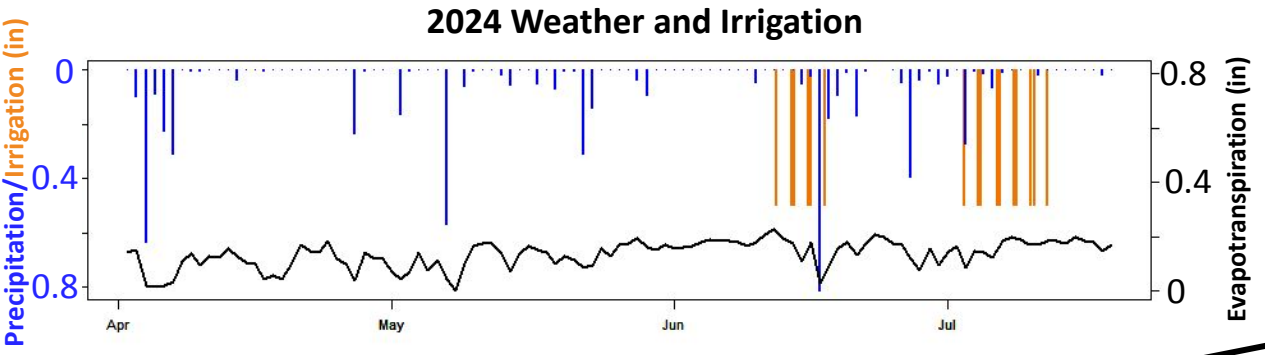


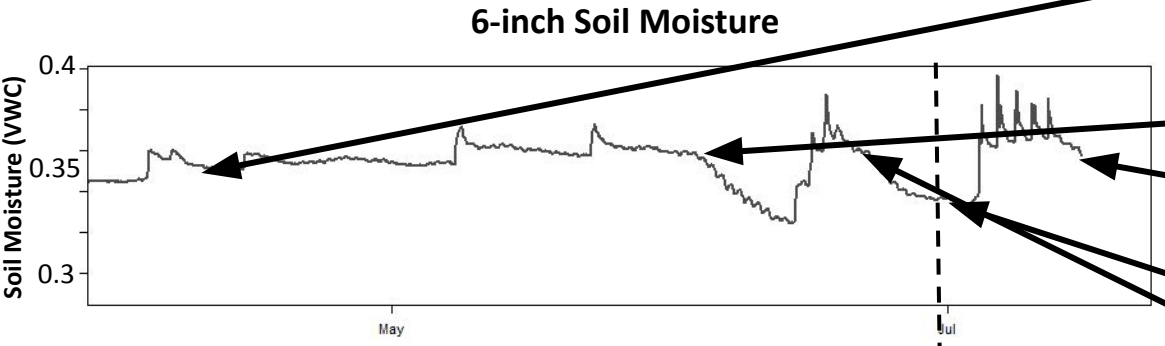


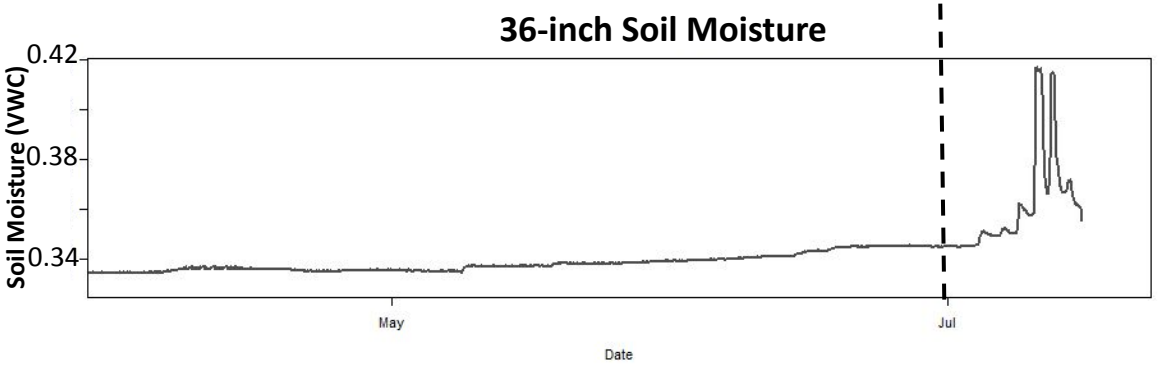
Low Responsiveness

High Responsiveness

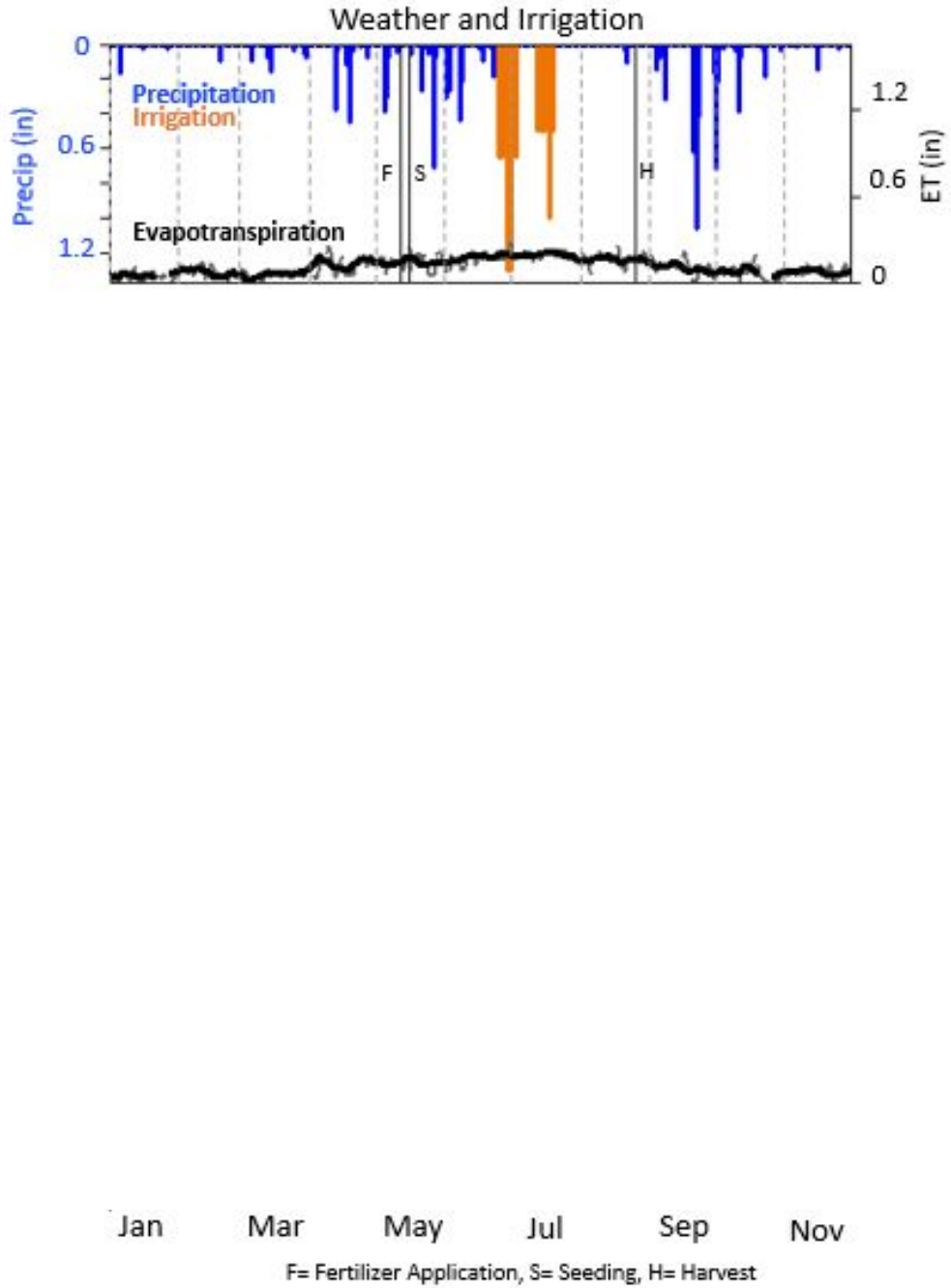
Crack Development and Preferential Flow







Nitrate Leaching Implications



Takeaways and Future Work

- Both soil texture and structure are important drivers of soil water transport abilities
- Deep percolation risk is highest on clay rich soils after the formation of surface cracks later in the summer
- Results suggest nitrate leaching losses from clay loam soils during the growing season
- Future Work
  - Expanded scope of soil moisture metric
  - Modeling work to quantify deep percolation and nitrate leaching losses
  - Extension guidance for producers

Acknowledgements

Committee:

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- Dr. Clain Jones
- Dr. Kent McVay
- Dr. Jasmine Neupane

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- Raeya Gordon
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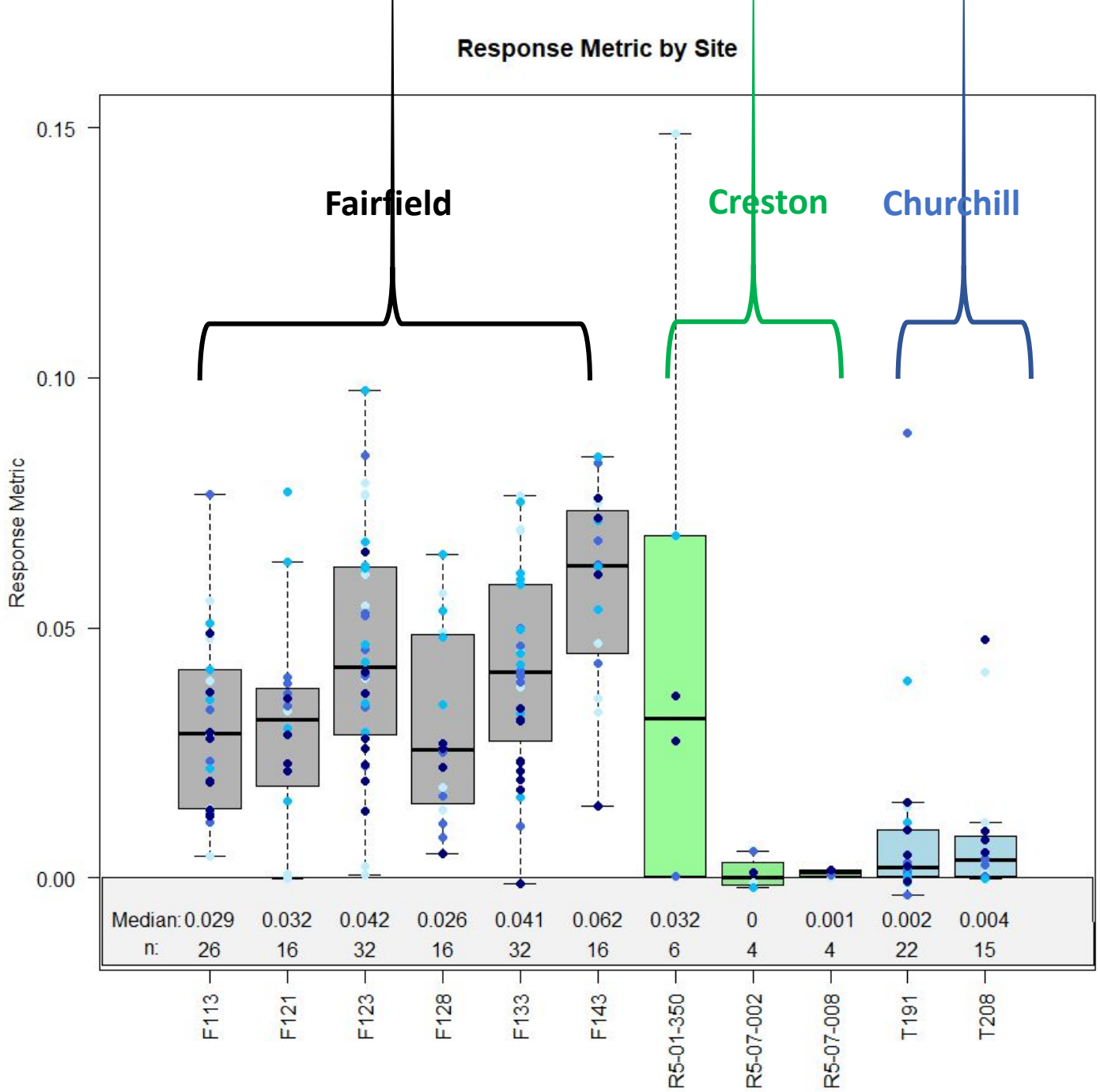
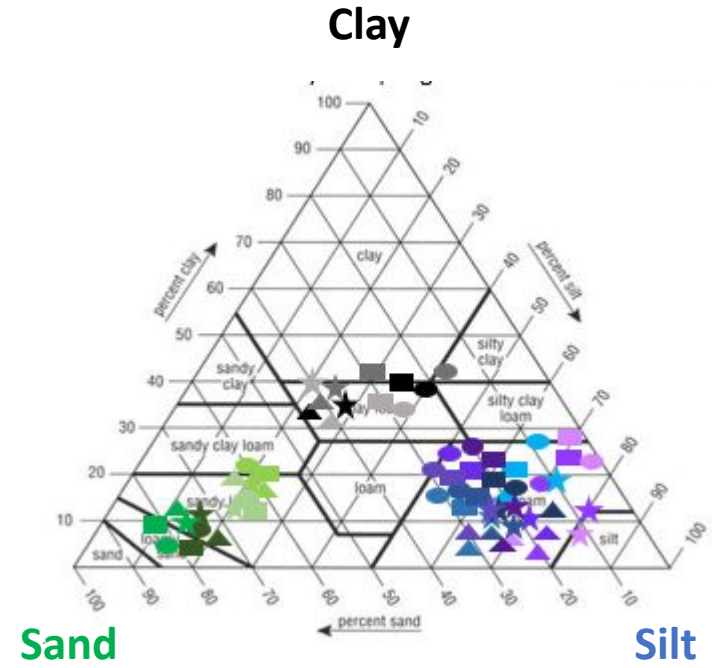
- Montana Water Center

Cooperating Producers in Churchill, Fairfield, and at MSU Northwestern Ag Research Center

Larger positive response

More Intense Drying

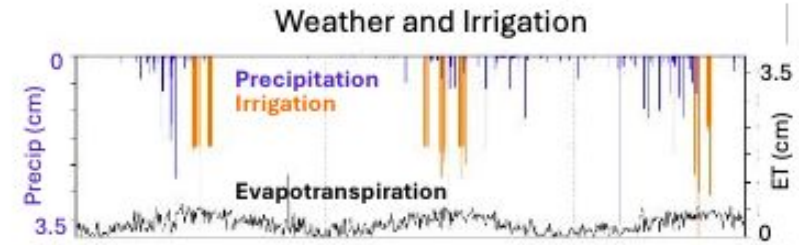


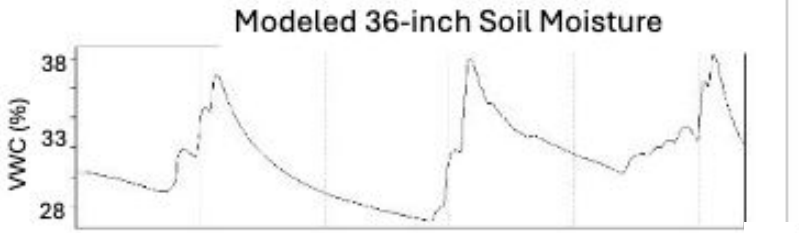


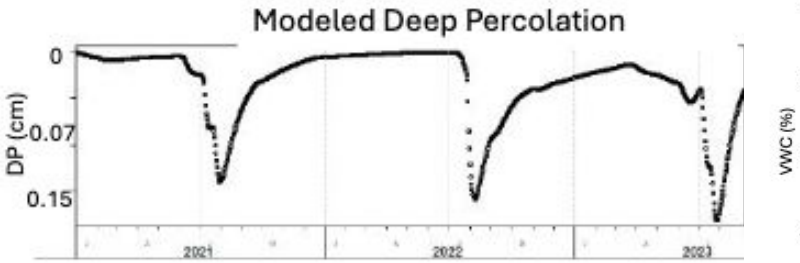
Driest 25%

Wettest 25%

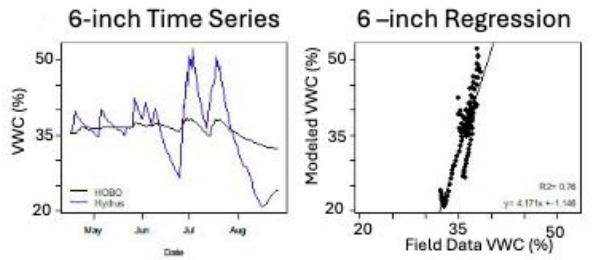
Model 1 Summary

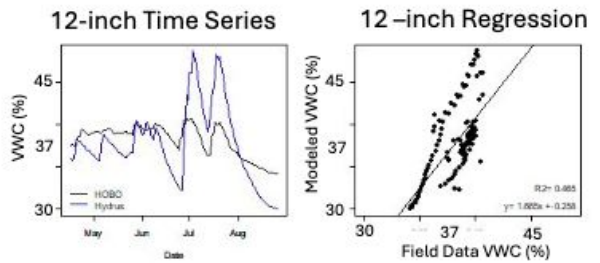


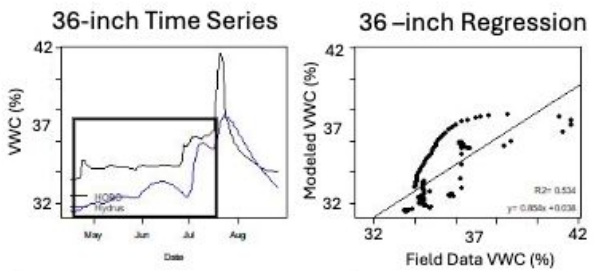




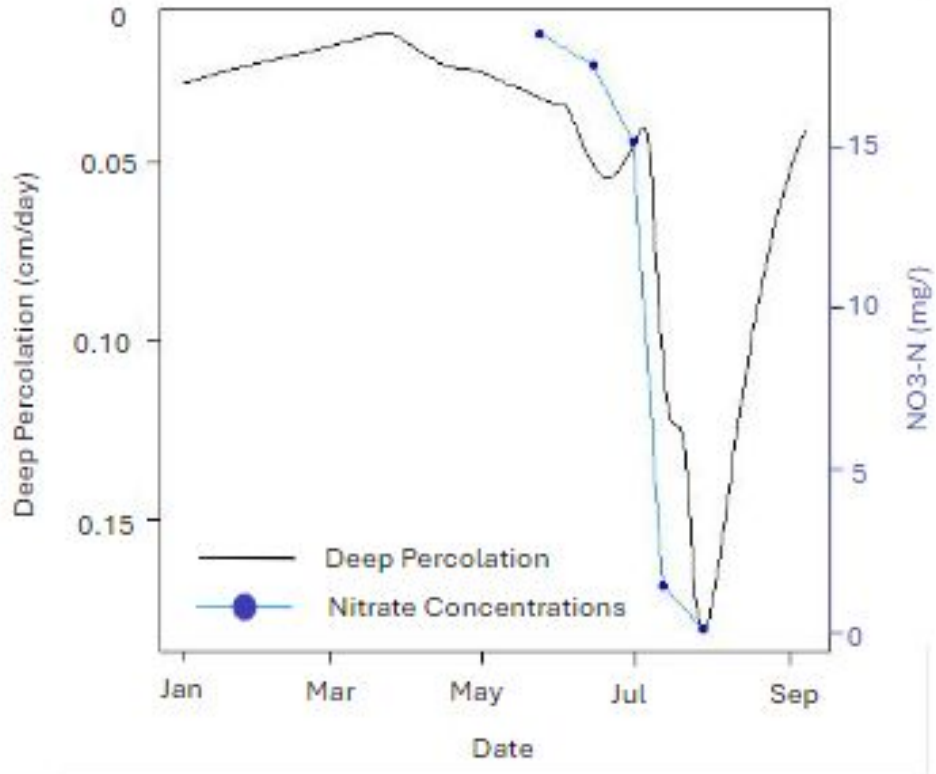
Model Scenario 1: Better Early Season Alignment

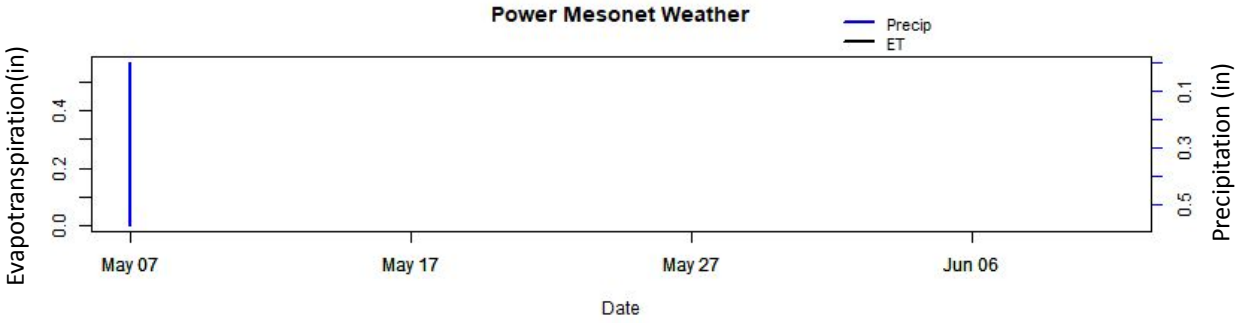


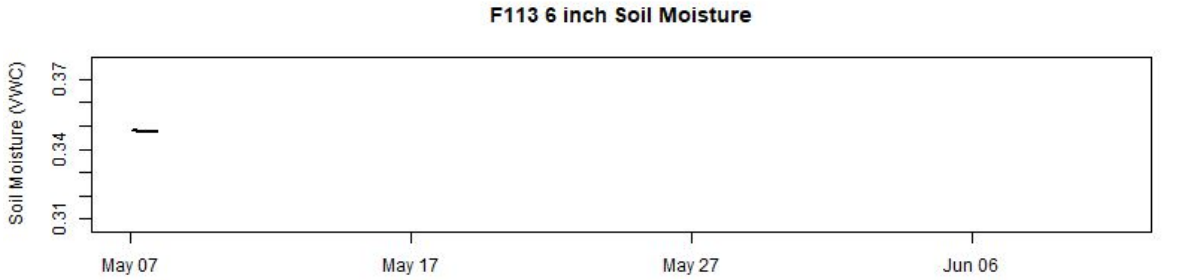




Model 1 Deep Percolation and Observed Nitrate




Power Mesonet Weather
Precip
ET
Evapotranspiration(in)
Precipitation (in)
0.0
0.2
0.4
0.5
0.3
0.1
May 07
May 17
May 27
Jun 06
Date

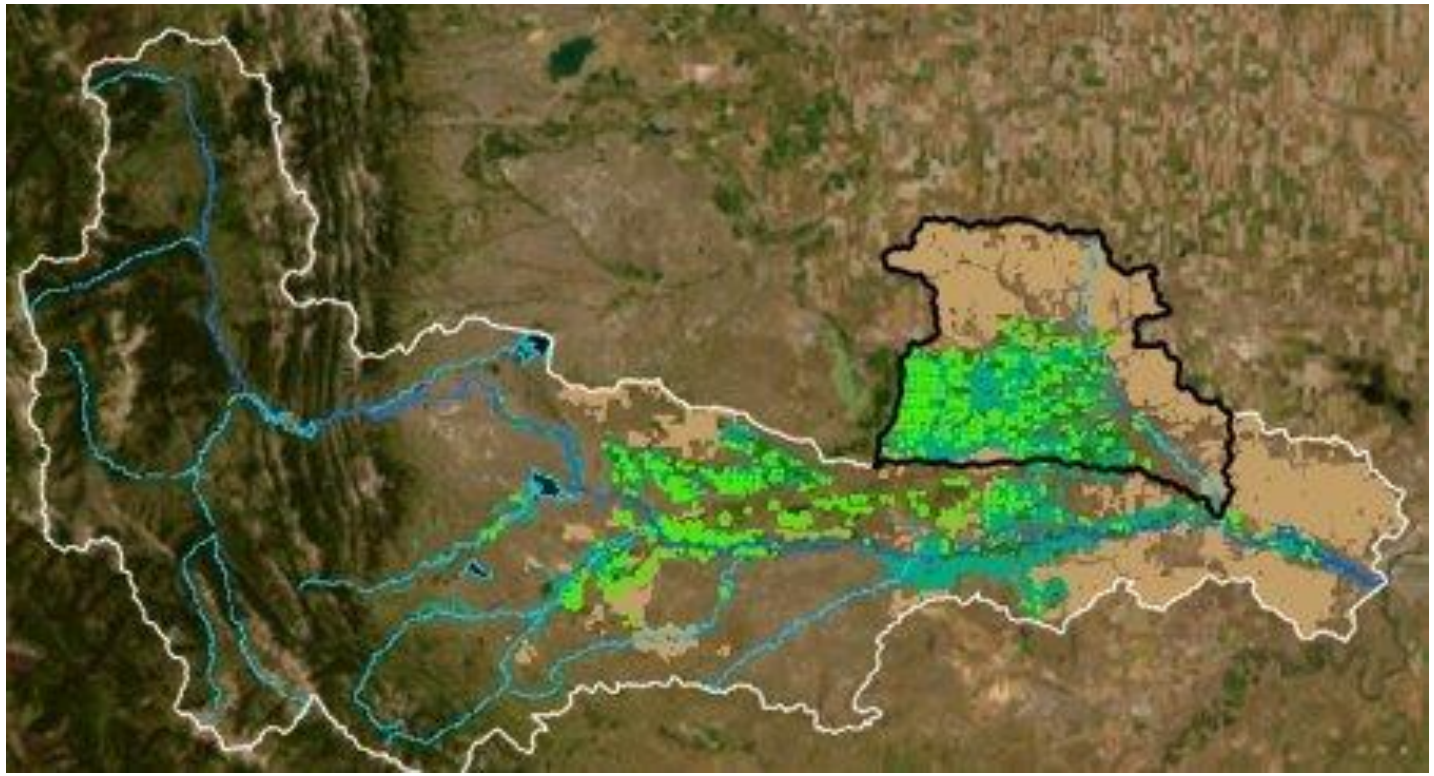

F113 6 inch Soil Moisture
Soil Moisture (VWC)
0.31
0.34
0.37
May 07
May 17
May 27
Jun 06

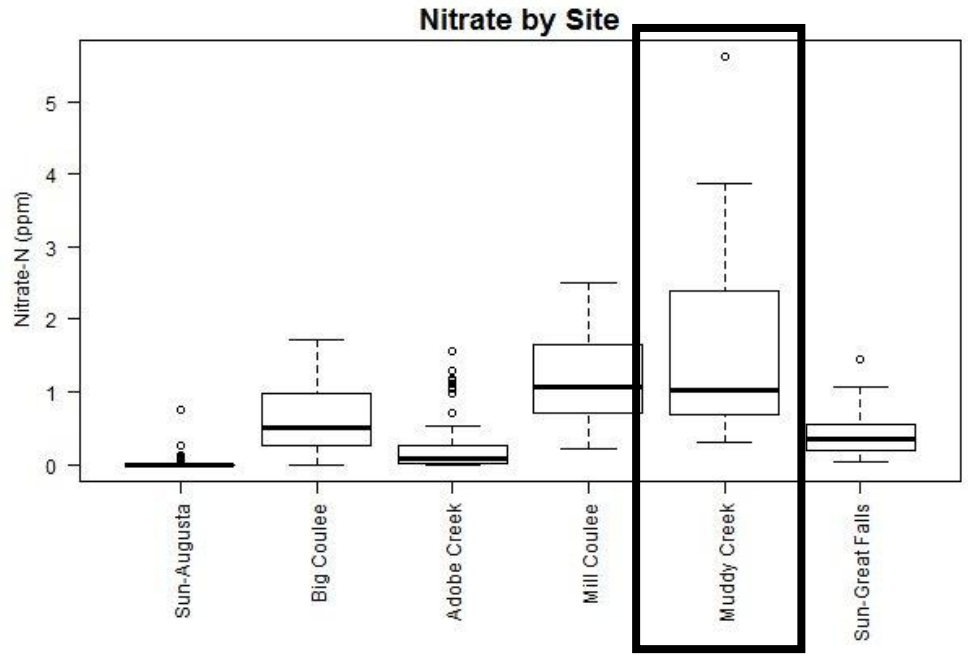

2024/05/07 10:27:29 7 ℃ 44 ℉ 0001

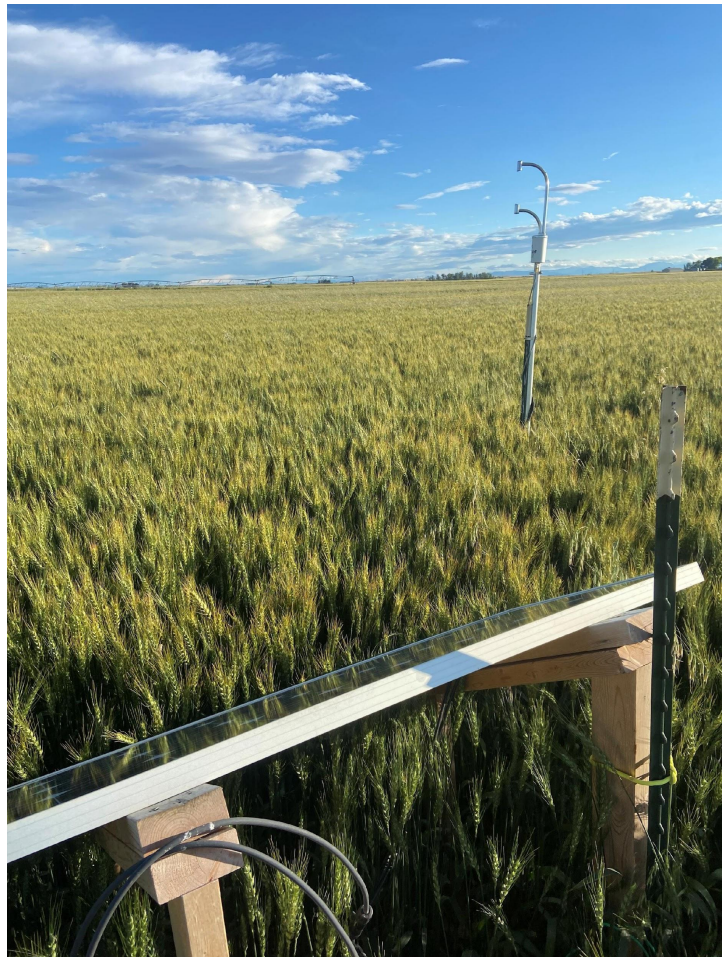

2024/05/30 17:14:40 17 ℃ 62 ℉ 0049

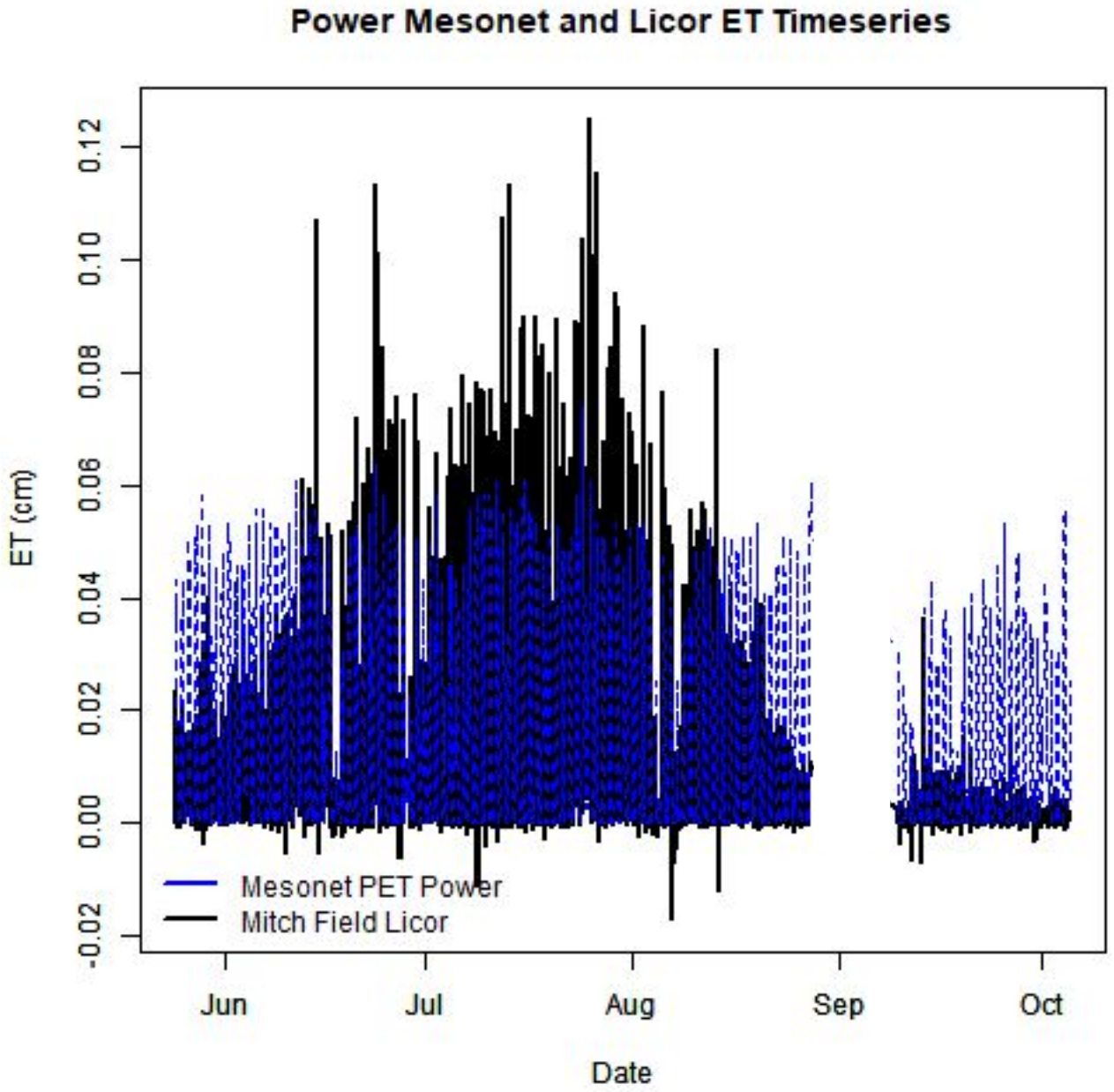

2024/06/02 17:14:40 23 ℃ 73 ℉ 0055


2024/06/11 10:07:18 20 ℃ 68 ℉ 0011




Nitrate by Site
Nitrate-N (ppm)
0
1
2
3
4
5
Sun-Augusta
Big Coulee
Adobe Creek
Mill Coulee
Muddy Creek
Sun-Great Falls




Power Mesonet and Licor ET Timeseries
ET (cm)
-0.02
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Jun
Jul
Aug
Sep
Oct
Date
Mesonet PET Power
Mitch Field Licor