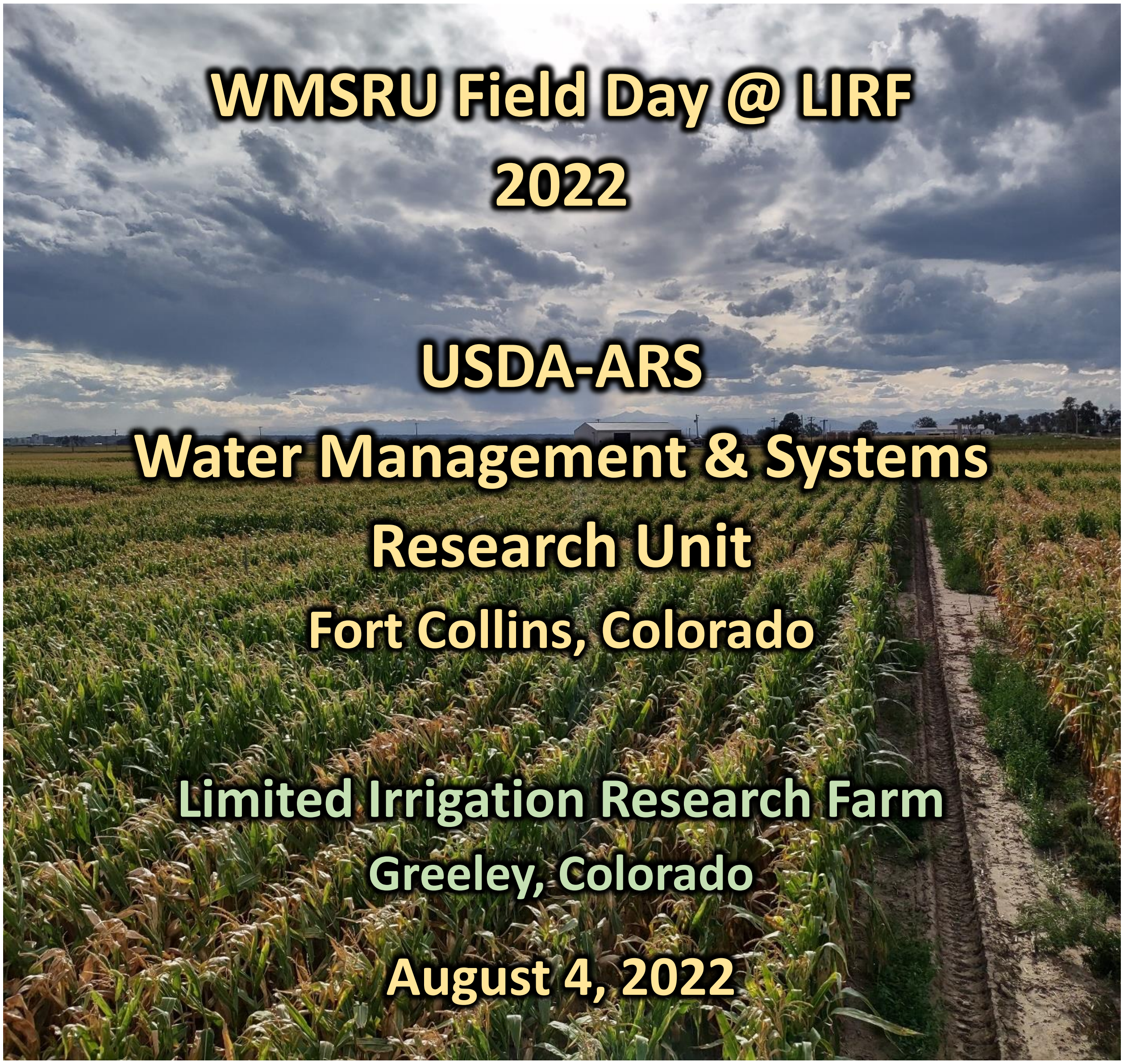

WMSRU Field Day @ LIRF
2022

USDA-ARS
Water Management & Systems Research Unit
Fort Collins, Colorado

Limited Irrigation Research Farm
Greeley, Colorado

August 4, 2022

USDA Agricultural Research Service

Northern Water

Colorado State University

WMSRU Field Day @ LIRF – Booklet Contents

Contents

Mission Statement – WMSRU

Water is precious.

Our mission is to develop systems and tools to help resource managers and farmers better manage and use water.

We work in areas *where rainfall is scarce*, from snow-fed mountain source waters to irrigated and dryland cropping systems.

We develop strategies to deal with changing climate, forest fire, competition for water, and the challenges of farming where rainfall is scarce.

Our research makes advances in plant drought tolerance, ecophysiology, remote sensing, micrometeorology, plant to watershed modeling, precision farming, irrigation management, and real-time decision support to bring economic value to stakeholders.

Limited Irrigation Research Farm (LIRF)

UAV Image (7/8/22)
Credit: Kevin Yemoto

Our Stakeholders and Partners

The Water Management & Systems Research Unit strives to build climate-smart agriculture and forestry systems in the western U.S. through research into drought-resilient dryland and limited-irrigation farming systems as well as wildfire and climate-resilient source-water forest ecosystems.

We work together with many agency, university, government, non-profit, and industry partners to research water issues that impact water-use stakeholders throughout the Rocky Mountain Front Range, the Western Great Plains, and water-limited regions throughout the world.

Hot Topics

- **Crops with water-efficient trait networks** are being studied that will provide both high yields and water-stress resilience in water-limited environments.
- **Precision irrigation research** at the **Limited Irrigation Research Farm** near Greeley Colorado uses Variable Rate Irrigation (VRI) systems along with sensors, monitoring, and modeling to apply irrigation when and where it is needed.
- **Wildfires in the western U.S.** are a huge threat to water supplies affecting rural and urban communities. Our research will measure and predict fire impacts, reduce fire danger, improve ecosystem health, and sustain urban and agricultural water supplies.
- **Climate-resilient, water-smart agricultural solutions** are being developed for precision agriculture and forest water-resource management using on-the-go sensors, remote sensing, big data, AI, and computer models.

Our Staff

Back: Tom Trout, Anoop Valiya Veettil, Nathan Lighthart, Jared Stewart, Bobbie Baxter, Ross Steward, Dave Barnard, Nora Flynn, Alana Galbiatti, Debbie Edmunds, Louise Comas, Kyle Mankin
Front: Tim Green, Josh Wenz, Garrett Banks, Jace Heryford, Kendall DeJonge, Katie Ascough, Sean Gleason, Cullen McGovern, Alex Olsen-Mikitowicz, Kevin Yemoto

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Dr. Dave Barnard, Ecosystem Ecologist
Dr. Louise Comas, Plant Physiologist
Dr. Kendall DeJonge, Agricultural Engineer/Irrigation
Dr. Sean Gleason, Plant Physiologist
Dr. Tim Green, Agricultural Engineer/Hydrology
Dr. Huihui Zhang, Agricultural Engineer/Remote Sensing

LIRF Farm Manager

Ross Steward

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Kevin Yemoto, Engineering Technician

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Dr. Sarah Tepler Drobnitch, Physiology (CSU)
Dr. Jared Stewart, Postdoctoral Fellow (NSF)
Dr. Bo Stevens, Microbial Ecologist

Seasonal Technicians, Interns

Brendan Allen, Katie Ascough,
Kit Bellefeuille, Chris Brackett,
Josh Brekel, Carolyn Dewey,
Tyler Donovan, Brian Duenas, John Ellis,
Jordyn Geller, Cameron Hunter,
Jacob Macdonald, Jordan McMahon,
Alex Merklein, Anna Pfohl,
Stephanie Polutchko, Jack Reuland,
Catherine Schumak, Megan Sears,
Jan Sitterson, Dan Spitzer, Ryan Wells

Field Day Agenda

2022 WMSRU Field Day @ LIRF
Thursday, August 4, 2022, 9:00 a.m. - 2:00 p.m.
Limited Irrigation Research Farm, Greeley, Colorado

9:00 Coffee & Donuts
In poster area. Provided by Northern Water.

9:00 Posters & Discussion with Researchers
Continuing throughout the day.

9:30 Field tours & Demonstrations
CoAgMet weather station, **Variable Rate Irrigation (VRI)** sprinkler (Kendall DeJonge, Ross Steward - ARS)
Irrigation Scheduling with Canopy Cover/Temperature, **Remote Sensing** with UAV/Drones (Huihui Zhang, Kendall DeJonge, Kevin Yemoto, Katie Ascough, Josh Wenz - ARS)
Narrow-row Corn Study (Jorge Delgado, Brad Floyd, Amber Brandt, Robert D'Adamo, Ross Steward - ARS; Jon Altenhofen - NWCD; Karl Whitman - CSU)
Sensors/Tools for Evapotranspiration, Crop Response & Farm Water Mgmt. (Jose Chávez - CSU, Jon Altenhofen - NWCD)
NASA SIF Tower (Andrew Schuh, Ian Baker, Stephen Ogle, Yao Zhang - CSU; Dave Barnard, Louis Comas, Huihui Zhang - ARS; Troy Magney, Francis Ulep - UCD; Mary Whelan - Rutgers)
Crop drought tolerance and water use (Sean Gleason, Stephanie Polutchko, Brendan Allen, Jared Stewart - ARS)

11:00 USDA-NRCS CEAP Round Table (optional)
Conservation effects on rangeland and cropland systems. Research briefs from USDA-ARS Rangeland Resources Management Research Unit, Soil Management & Sugar Beet Research Unit, and Colorado State University researchers.

12:00 LUNCH
Provided by Northern Water.

12:30 Lunchtime Talks
Kyle Mankin/Pete Kleinman (USDA-ARS): Welcome and Introductions
Dave Barnard (USDA-ARS): Mountain hydrology impacts agricultural production
Jon Altenhofen (Northern Water): Monitoring, managing, and documenting consumptive use savings to support Alternative Ag Water Transfer Methods

1:15 Depart for Hop Farm Tour
CEAP Tour (optional; self-transportation)
Hosts: Pete Kleinman - ARS, Troy Bauder - CSU

1:30 Depart for Drake Farm Tour
Cropland to CRP Conversion USDA-ARS research site (optional; self-transportation)
Hosts: Tim Green, Rob Erskine - ARS

2:00 Wrap up @ LIRF

Field Tour Stop 1:
CoAgMet Weather Station & Variable Rate Irrigation (VRI) Sprinkler

Kendall DeJonge, Ross Steward

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

As competition and uncertainty of water supplies becomes more common, irrigated agriculture is facing increasing demand for water, and farmers are increasingly having to make management decisions which consider deficit or limited irrigation. Since 2008, the Limited Irrigation Research Farm (LIRF) near Greeley, Colorado, has performed research on limited irrigation of crops, with one of the primary goals to expand the knowledge of how to maintain crop productivity through optimized management of limited water. This tour stop gives a brief discussion of the irrigation systems, the micrometeorological network used to quantify crop needs, and a demonstration of the new Variable Rate Irrigation (VRI) linear sprinkler system.

The primary onsite well pumps groundwater from a depth of ~50 feet, at a peak rate of ~500 gpm. The well water can then be used to supply some on-farm canals for siphon tube irrigation, as well as the majority of the farm which is under pressurized irrigation systems: ground sprinkler, linear sprinkler, and subsurface drip. For the pressurized systems, the booster is set at a desired pressure for the irrigation type, and flow is regulated to maintain the setpoint pressure. A backflow flush filtration system is required to keep sediment out of the pressurized systems, as well as maintain operating pressure.

The micrometeorological station is on the Colorado Agricultural Meteorological Network (CoAgMet, station GLY04) which is designed to provide weather information and reference evapotranspiration (ETref) to farmers, researchers, and other local users. By measuring temperature, relative humidity, solar radiation, and wind, we can determine the ETref at the site, which can then be used to scale to crop ET (ETc) for various crops, which is useful data for irrigation scheduling and water monitoring. The station is set on a well-watered grass reference crop, and data collection also includes precipitation and soil temperature.

The VRI linear sprinkler was recently installed and first used for the 2021 field season, which was previously irrigated by surface drip since 2008. The sprinkler is a Lindsay Zimmatic model with full VRI capabilities, where each nozzle can be pulsed on/off by a solenoid valve to adjust irrigation application amounts as needed. Irrigation amounts are programmed into Lindsay FieldNet online interface, where field polygons are customizable by size and each irrigation depth. This equipment offers many new advances to our research program, including the ability to irrigate outside of the growing season to fill the soil water profile and/or leach salts and nitrates, irrigate prior to or immediately after planting to promote germination, rearrange and rerandomize plot size and design, and manage multi-crop experiments at the same time. Current experiments involve a sorghum variety trial with irrigation treatments, as well as maize irrigation scheduling (next tour stop) based on soil water balance, canopy temperature, crop models, energy balance, and FAO-56 crop coefficients.

To combat runoff issues during large irrigations or rainfall events, a Dammer-Diker tillage implement was used to create surface roughness between the crop rows.

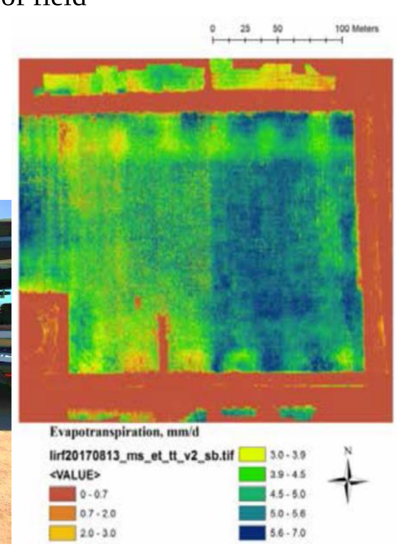
Field Tour Stop 2:
Irrigation Scheduling with Canopy Cover/Temperature, Remote Sensing with UAV/Drones

Huihui Zhang, Kendall DeJonge, Kevin Yemoto, Katie Ascough, Josh Wenz

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

Agricultural water supplies in arid and semi-arid regions in the U.S. are experiencing uncertainty and limitations due to climate variability and extreme drought, wildfires, interstate compacts, declining aquifers, and water delivery restrictions. These water limitations increase the need to optimize irrigation management. Such management requires accurate estimation of crop water status, crop water use, and soil water availability on both a spatial and temporal basis. Sensors are becoming more advanced and affordable, which can provide real-time data for farmers to answer questions like "When does crop need water? How much water does crop consume? Where should I irrigate? and is my crop experiencing water stress?". However, processing and interpreting this data can be complex, especially when combined with modern irrigation technology such as variable-rate irrigation (VRI). Therefore, our research aims to develop spatially variable yet adaptable and practical irrigation scheduling methods to improve VRI by linking soil, weather, plant stress measurements, crop modeling, and remote sensing.

ARS scientists in Fort Collins, Colorado, successfully used unmanned aerial vehicles, drone-based and ground-based sensors, and smartphone applications to measure corn canopy and crop water stress based on accurately measured canopy temperature. We tested different irrigation control methods by deciding the amount and timing of irrigation, including one using a traditional soil water balance approach, two using canopy temperature-based crop water stress, and one using a crop model and remotely sensed crop leaf area. We were able to successfully evaluate the efficacy of each of these methods for scheduling full and deficit irrigation using actual plant transpiration measured by sap flow sensors, which measure the process of water movement through a plant to its evaporation. We found that methods based on canopy temperature were capable of accurately indicating water stress and quantifying the reduced water use. Combining these two simultaneous measurements of stress and water use with data from nearby micrometeorological stations, we were able to make real-time irrigation decisions. We also found that the integration of crop model and remote sensing was able to effectively control irrigation with few requirements of field data. Furthermore, importantly, measurement of plant stress and crop water use using drone-based remote sensing provided both temporal and spatial information to inform irrigation at the farm scale. Our future works plan to integrate these high-resolution datasets with our VRI sprinkler to demonstrate the capabilities of precision irrigation at finer scales.



We expect that this technology will be valuable to irrigation system manufacturers, agronomists, and farmers with the need to optimize crop production with limited water.

Field Tour Stop 3:
Use of Narrow Rows in Sprinkler-Irrigated Corn Systems to Increase Silage and Grain Yields, Nitrogen and Water Use Efficiencies, and Economic Returns

Jorge Delgado, Brad Floyd, Ross Steward, Amber Brandt, Robert D'Adamo

USDA-ARS, Soil Management & Sugar Beet Research Unit, Fort Collins, CO

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

Jon Altenhofen

Northern Water (Northern Colorado Water Conservancy District)

Karl Whitman

Agricultural Experiment Station, Colorado State University

Studies about the potential to use narrow rows to increase silage or harvested grain yields and nitrogen and water use efficiencies and economic returns were conducted from 2018 to 2021 at the CSU-Agricultural Research, Development and Education Center (ARDEC) near Fort Collins, Colorado. In 2022 we expanded to two demonstration studies at ARDEC where two 4-acre fields were planted. At each field, 2 acres were planted in 15-inch (narrow) rows and 2 acres were planted in 30-inch (conventional) rows. Additionally, a set of narrow rows comparing the 15-inch and 30-inch rows is being monitored at the Limited Irrigation Research Farm (LIRF) in Greeley, Colorado. At LIRF we are also comparing 20-inch rows to twin rows.

From 2018 to 2021, we found higher silage and/or harvested grain with narrow rows in all our corn studies. In 2018 we increased the harvested grain production with 15-inch rows by 18.9 bushels per acre (10% higher) compared to 30-inch rows with the same plant population and irrigation. In 2019 and 2020 we doubled the population in the narrow rows and compared the 15-inch versus the 30-inch rows with the same nitrogen and water applications. The narrow rows increased silage production by an average of 4 tons per acre (dry weight) when compared to the 30-inch rows, which was an increase in production of 43%. The harvested grain was increased by an average of 14.5 bushels per acre with the 15-inch rows, 10% higher than the 30-inch plots. In 2021, 15-inch rows with a 36% higher plant population increased harvested grain by 42.5 bushels per acre, 18% higher than 30-inch rows. In 2021 the 15-inch rows produced 3.3 tons of dry matter silage (32% higher) per acre compared to 30-inch rows. We accounted for the increase in seed cost and when we doubled the population, we found that the narrow rows would contribute to $99,000 to $195,000 in higher economic returns for a 1,000-acre farm. This estimate was obtained assuming 10% lower response in hay and harvested grain yields. Our estimate used 3 and 6 dollars per bushel and $80 per ton of hay. When we used the results from a 36% higher population, we found that the economic returns for a farmer with a 1,000-acre farm would increase by an estimated $170,000 to $353,000 with the same assumptions mentioned above.

Since we found positive responses in corn yields with the same nitrogen and water application, there was a significant increase in agronomic nitrogen use efficiencies with 15-inch rows compared to 30-inch row spacing. The water use efficiency (production of grain or silage per unit of water input from rain or irrigation during the growing season) was also higher. The 2022 preliminary assessment of the two silage demonstration projects at ARDEC shows an advantage to narrow rows. Preliminary results also suggest that narrow rows are advantageous for the fully irrigated Channel hybrid compared to the 30-inch rows at ARDEC and LIRF. When 2022 plots are harvested, we will determine if these preliminary results based on visual observations are supported by quantitative measurements. Since this is the first year that we implemented a study of limited irrigation with narrow rows, the data will be analyzed and new studies for 2023 will be planned to incorporate the results from and lessons learned in 2022.

Field Tour Stop 4:
Sensors/Tools for Evapotranspiration, Crop Response & Farm Water Management

Jose Chávez

Department of Soil and Crop Sciences, Colorado State University

Jon Altenhofen

Northern Water (Northern Colorado Water Conservancy District)

The following field sensors are used to understand the theory and science of the Energy Balance and computation of crop evapotranspiration-ET. The Energy Balance is:

Net Radiation = Sensible Heat + ET + Soil Heat Flux

Measuring all these terms accurately in different ways provides confidence in the crop water use-ET.

<u>Sensors Include</u>: Canopy temperature by different techniques at different heights and angles and air temperature/humidity at different heights, solar and net radiation, soil heat flux, soil moisture, wind speed at different heights, eddy correlation flux system, canopy reflectances and canopy cover.

This extensive monitoring/measuring of crop water needs coupled with visual plant responses lead to key indicators and parameters that can be used to manage/mitigate stress effects such as canopy cover and visual crop signs as related to crop growth stage.

With a good computation and understanding of crop water needs-ET coupled with measuring water applied and a soil water balance, deficit irrigation strategies can be developed with the goal of maintaining yield with less ET. This can help with farmer response to droughts and/or the saved water from reduced ET can be leased to cities through approved augmentation plans.

At LIRF, we stress grain corn crops to the maximum extent and look at various practices that could maintain the yield such as drought tolerant varieties, plant population, plant row spacing and irrigation amount and timing as a function of irrigation system whether sprinkler or surface/furrow irrigated. Managing water stress involves (1) avoid it (start with full soil water profile), (2) tolerate it (variety and row spacing), and (3) recover from it (irrigation frequency and amount).

For good irrigation management whether fully irrigating to meet total ET or practicing a deficit irrigation strategy, measuring water applied is essential through a flowmeter, flume or simply counting siphon tubes. The goal of any irrigation is to meet ET by refilling the soil profile efficiently—whether meeting full ET so no water stress or deficit irrigation allowing controlled water stress and a reduction in ET. A goal at LIRF is providing only 6 to 9 inches of ET from the irrigation water depending on rains where fully irrigated is 18 inches from the irrigation water on average for fully irrigated. And then of course trying to maintain grain corn yields through varying agronomic practices.

Field Tour Stop 5:
NASA SIF Tower: Integrating Field-Based Measurements and Models to Evaluate Solar Induced Fluorescence as a Predictor of Dryland Crop Productivity

Andrew Schuh, Ian Baker, Stephen Ogle
Cooperative Institute for Research in the Atmosphere, Colorado State University

Dave Barnard, Louise Comas, Huihui Zhang
USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

Yao Zhang
Natural Resources & Ecology Laboratory, Colorado State University

Troy Magney, Francis Ulep
Department of Plant Sciences, University of California–Davis

Mary Whelan
Department of Environmental Sciences, Rutgers University

During the past few decades, United States croplands have been a modest sink for carbon dioxide (CO_2). In addition, there has been re-emerging interest in encouraging carbon sequestration through croplands in national/global policies and carbon markets. As a result, there is increasing interest in regional carbon models used to quantify the national greenhouse gas inventory for the U.S. Especially important is ensuring that crop carbon models are accurate and factor crop stressors such as drought and increased temperatures.

In this NASA–USDA–CSU–UC-Davis collaboration, we are using tower-based remote sensing instruments complemented by a suite of field measurements to identify how short-term crop stress influences annual C sequestration and yield. Such influences can directly impact carbon inputs to soils and regional CO_2 fluxes. Our study is centered on arid cropland systems that are either rainfed or have limited irrigation. The research sites include two established USDA field operations, the Limited Irrigation Research Farm (LIRF) in Greeley, Colorado (maize), and Central Great Plains Research Station in Akron, Colorado (winter wheat), with measurement campaigns in 2022 and scheduled for 2023.

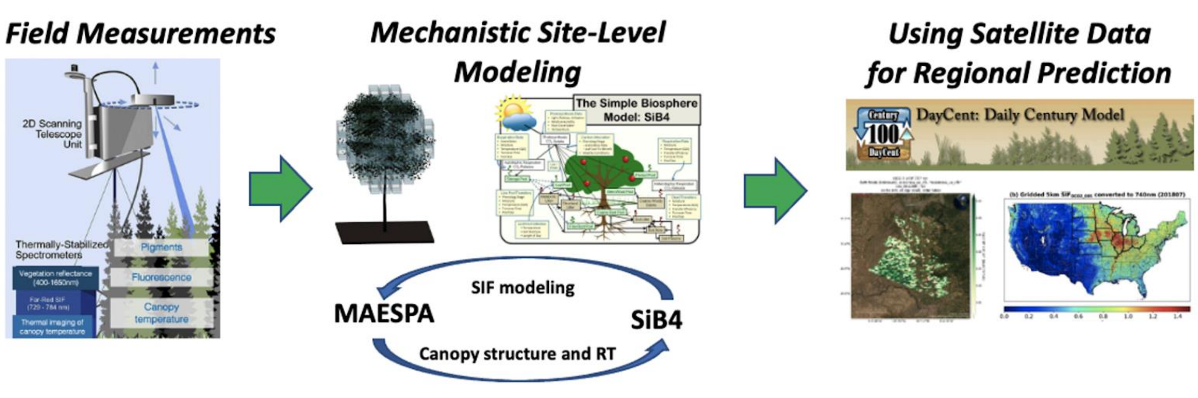


Figure 1: Simple Flowchart of Research Components

The tower instrument, highlighted at the LIRF 2022 Field Day, collects a suite of remote sensing metrics (i.e. NDVI) including one called solar-induced fluorescence (SIF). SIF, which is also measured from several satellite instruments, has emerged as a reliable proxy of plant photosynthesis. It has been shown to be a powerful predictor of crop yield. For example, higher SIF values suggest more photosynthesis and potentially a higher crop yield. However, there is uncertainty about how the SIF/crop yield relationship might change under crop stress conditions. To investigate this question, the SIF-tower instrument will be supplemented with ongoing measurements including soil moisture, atmospheric measurements, sap flow, CO_2 eddy covariance, in addition to vegetation indices and routine spectral imagery from daily autonomous drone flights.

The measurements compiled from our field campaigns will be used to develop a SIF-based production algorithm within the DayCENT Ecosystem Model, which simulates carbon fluxes. The local model created (focused on Akron and LIRF) will be scaled to croplands within the western U.S. With global coverage of satellites capable of measuring SIF, the driving principles and results from our study could have broad applicability across water-limited cropland regions around the world, e.g., wheat in Russia, China, and India, maize in China, Brazil, and India. This could result in measuring cropland-related CO2 fluxes with higher accuracy and determining its impact on the global carbon budget.

Field Tour Stop 6:
Crop Drought Tolerance and Water Use

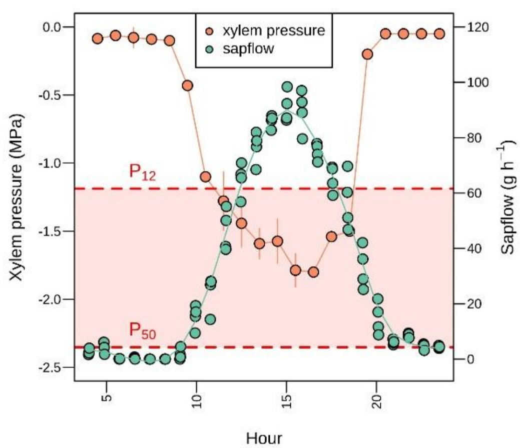
Sean Gleason, Stephanie Polutchko, Brendan Allen, Jared Stewart, Jordan McMahon
USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

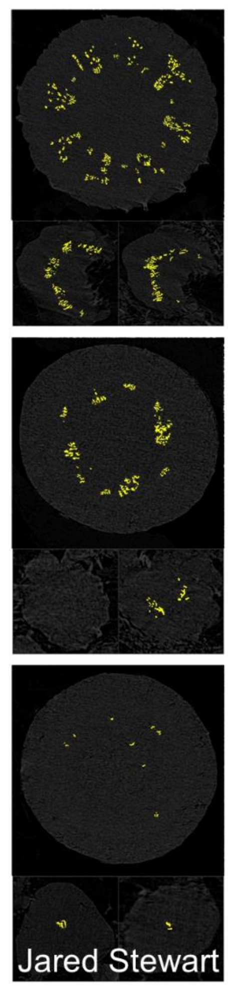
Crop improvement programs aim to increase yield per unit resource consumed, e.g., light, space, nutrient, and water. Plants grow by exchanging large volumes of water for atmospheric CO_2, and as such, crop growth and grain yield is supported primarily through this important exchange. However, the water-CO_2 exchange rate is costly – with crop species losing/"spending" between 260 to 1140 grams of water per 1 gram of atmospheric CO_2 taken in.

This considerable expense arises directly from the exposure of wet, internal cellular surfaces to the dry atmosphere, a condition necessary for the uptake of CO_2 into plant photosynthetic cells. An important implication of this system is that large volumes of water must be transported long distances through plant conductive tissues (roots, stems, leaves), explaining why natural selection has favored highly efficient water transport systems in crop species.

High growth rates are therefore usually closely aligned with: 1) the capacity of the root system to access soil water, 2) the capacity of the vascular system to deliver this water to the canopy, where it is converted into sugar and eventually grain, and 3) the ability of photosynthetic machinery to convert this water into plant tissues and grain. Taken together, the performance of crop plants depends not on single traits (e.g., leaf traits, root traits, photosynthesis traits) to provide efficient performance, but rather on "networks" of plant traits, working together in a coordinated fashion.

At this stop on the tour we provide an overview of the science underpinning the ability of crop species to achieve high rates of growth in both fully watered and water-limited environments. We also discuss how these scientific concepts are being used to improve crop species, and also how basic plant science will make crops grow faster in the future.



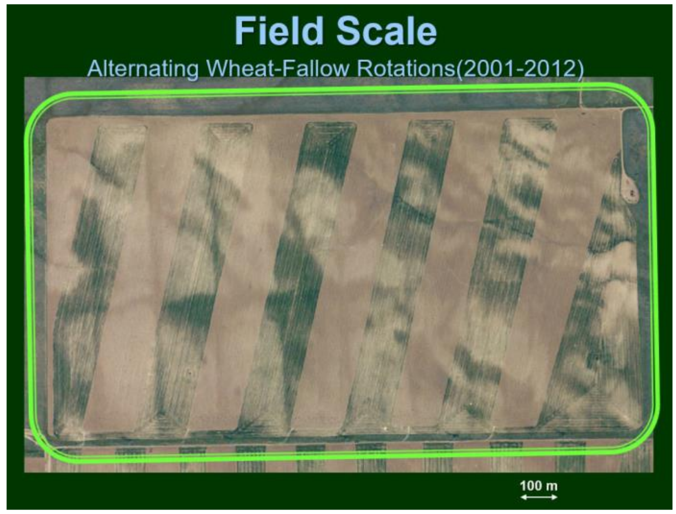


Poster:
Two decades of data collected to study spatial patterns in a dryland field under wheat-fallow cropping and CRP

Rob Erskine, Tim Green, Lucretia Sherrod, Dave Barnard, Jacob Macdonald, Adam Mahood, Kevin Yemoto, Huihui Zhang, Kyle Mankin

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

The poster will show examples of the data collected since 2001 on the Scott field at the Drake Farm. Measurements and analyses reveal patterns above and below ground of surface runoff, soil moisture and temperature, soil hydraulic properties, soil erosion and deposition (based on changes in surface elevation), and soil carbonates. The field was planted in a mix of perennial seeds under the NRCS Conservation Reserve Program (CRP) in 2013 and 2014. Since then, we installed new meteorological instruments and conducted vegetation surveys (not shown here).



Join us after lunch on the Drake Farm tour to see what you can see and learn how CRP has changed things!

Poster:
The Hidden Agricultural Microbiome

Bo Maxwell Stevens

Postdoctoral Microbial Ecologist

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

There are billions of organisms below our feet and invisible to our senses that are performing a multitude of beneficial services. For millions of years, plants like maize have cooperated with these microbes to acquire nutrients and water. In fact, all life evolved within a microbial world. The potential usefulness of these microbes is unlimited, but we first have to identify them and find out what they are doing. To that end, we are using next generation sequencing to identify these microbes within nitrogen and drought experiments to determine which may be facilitating maize productivity. Our goal is to get these microbes to do the heavy lifting so that we can reduce agricultural inputs and have resilient crops.

Poster:
Central Great Plains Research Station History 1907-2022 – Akron, CO

Maysoon Mikha, Kyle Mankin

USDA-ARS, Central Great Plains Research Station, Akron, CO
USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

The USDA-ARS Central Great Plains Research Station in Akron, CO was established in 1907 on 226.7 acres: 66.7 acres of buffalo-grama grass provided by Washington County commissioners Louis B. Wind, Mark B. Gill, and Elmer E. Brown, together with 160 acres of state land set aside from homestead entry by M.F. Vance, a local farmer-rancher. From June 19 to July 1, 1907, 47 acres of the original buffalo-grama grass sod were broken out for research study. The construction of the first barn began in September 1907. A well was drilled in October, with water found at 90 ft. A windmill was installed in November 1907 and a house was completed by the end of the year. The first experiments were established in 1908 and 1909.

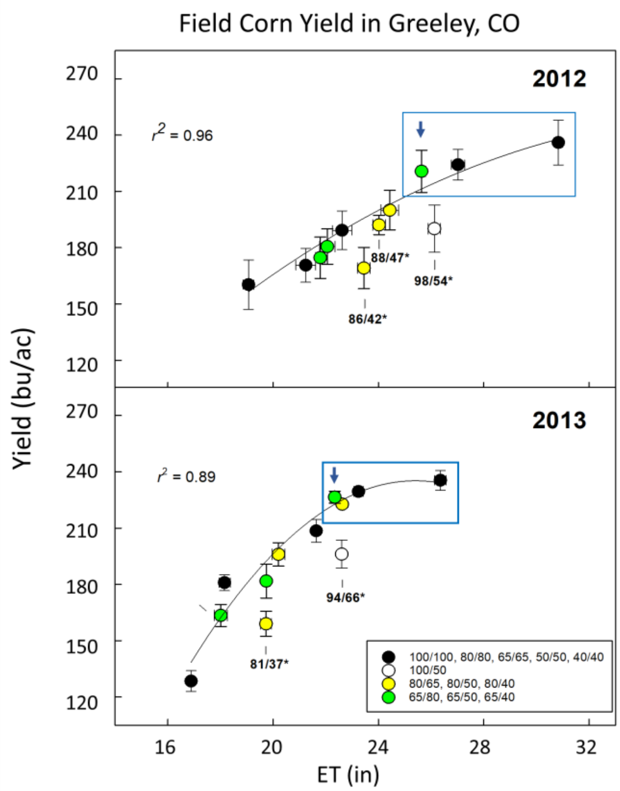
Poster:
Options for Optimizing Limited On-farm Irrigation

Louise Comas, Kyle Mankin, Debbie Edmunds, Sean Gleason, Huihui Zhang, Kendall DeJonge

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

Field corn is the preferred agronomic crop for many irrigated farms in the Northern Great Plains, but many farms do not have enough irrigation water to meet its full water needs. There are, however, currently several options for these farms.

Strategic deficit irrigation (seasonally applied) can maintain economic yields while saving crop water used. The most critical growth period to apply irrigation for corn is at tassel to get pollination. The next most important period is during grain fill (the period after pollination). We were able to maintain yield with 17% less crop water used by applying a target of 65% irrigation in the last half of vegetative stage, the 5-week period prior to tassel. Significant yield losses can occur (even if there has been good pollination and seed set) when corn is fully irrigated through the first half of the growing season but has limited water availability at the end of the season during grain fill. If there is risk of irrigation shortfall at the end of the season, it may be prudent to apply deficit during the late vegetative period.



Switching a portion or all of a farm to alternative crops that use less water may be a good option to maximize farm productivity when water shortfalls are anticipated. Sorghum is one alternative for current field corn producers that is planted on a similar row spacing. Maximum grain sorghum yield in Greeley, CO requires ~65% of the crop water use of field corn (~17 inches; 9 inches less than corn). Forage sorghum and other forage crops can use even less water.

Deficit irrigation can be used strategically in corn to save ~17% of crop water use and provide some buffer from worse yield losses. However if water shortages are expected, especially late in the season, planting a smaller portion of the farm in corn is prudent. In this case, alternative crops can be used to maximize productivity on the farm.

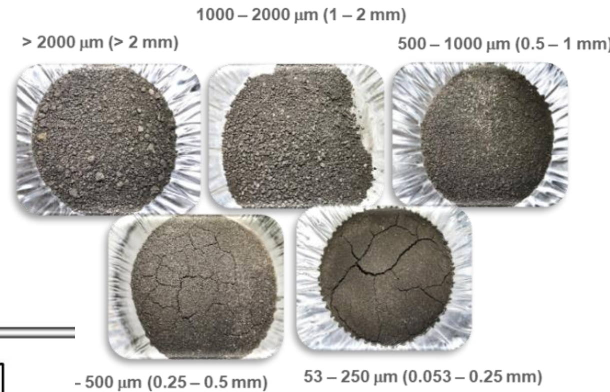
Poster:
Soil Structure Stability under Different Management Practices

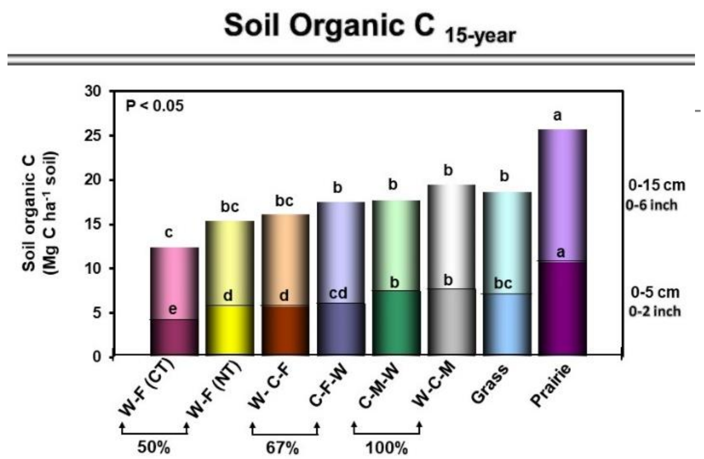
Maysoon Mikha, Tim Green, Kyle Mankin

USDA-ARS, Central Great Plains Research Station, Akron, CO

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

Land use and agricultural management decisions such as tillage practices, organic amendments, and cropping intensity can alter soil structure stability and overall soil health. Soil aggregation is an important indicator of soil structural stability, erodibility, nutrient dynamics, and soil organic carbon (SOC) conservation.





Poster:
Crop Growth-Stage Response to Water Stress for Corn, Dry Beans, Sunflower & Winter Wheat

Kyle Mankin, Debora Edmunds, Ryan Wells, Holm Kipka, Nathan Lighthart, Tim Green

USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

This study is testing a new water stress method in UPGM that (a) defines the growing degree days (GDDs) needed for a crop to progress through each growth stage under water non-limiting and water limiting conditions, and (b) considers the degree of water stress (such as with limited irrigation) in modeling crop development. We are developing and testing phenological parameters for the following crops: Corn, Winter wheat, Soybeans, Winter barley, Sorghum, Spring wheat, Sunflower, Spring barley, Hay millet, Proso millet, and Dry beans. Each crop has different timing between growth stages. Growth stage timing is different between water non-limiting and water limiting conditions. Stress can affect stages within a crop differently. Stress may speed up or slow down the vegetative or reproductive portion of crop development. The new water stress method more directly simulates crop response to water stress, calculates the required GDDs daily based on Water Stress Factor (soil moisture), and calculates a percentage of completion by dividing the simulated GDDs for the day by the required GDDs for the day.

Poster:

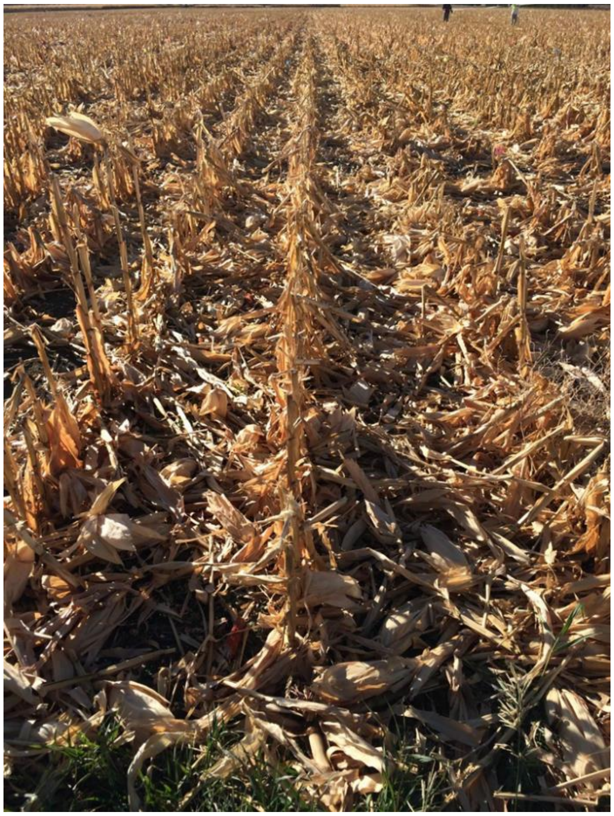
Does No-tillage Mitigate Stover Removal in Irrigated Continuous Corn? A Multi-location assessment

Catherine Stewart, Damaris Roosendaal, Aaron Sindelar, Virginia Jin, Marty Schmer

USDA-ARS, Soil Management & Sugar Beet Research Unit, Fort Collins, CO

No-tillage (NT) may reduce the negative effects on soil properties from corn (Zea mays L.) stover harvest. However, few long-term continuous corn irrigated production studies have quantified these effects. In this study, we evaluated three long-term sites in

Nebraska and Colorado across a range of precipitation and soil organic C (SOC) stocks. We measured SOC, '13C of SOC, soil microbial biomass (SMB) and composition (PLFA), water stable aggregation, and other soil indicators including P, K, and EC. Overall, residue removal decreased SOC stocks by 6% and soil aggregation by 10% in the 0-30 cm depth, with the majority of the change observed in the surface (0 to 7.5 cm). Residue harvest did not change SMB or change soil microbial community structure, suggesting that high plant productivity buffered these communities from residue-harvest impacts under NT, despite SOC loss from increased microbial decomposition of soil C. These sites had lower SOC stocks and aggregation compared to residue retained treatments, suggesting that conservation tillage alone is inadequate in maintaining erosion protection and soil function.



Poster:
Fire Effects on Evapotranspiration using Landsat-based SSEBop

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We used the Simplified Surface Energy Balance model (SSEBop) to study the impact of fire on remote-sensing actual evapotranspiration (ETa) in four fire-impacted areas: 2002 Million Fire (CO), 1996 Hondo Fire (NM), 2002 Montoya Fire (NM), and 2000 Cerro Grande Fire (NM).

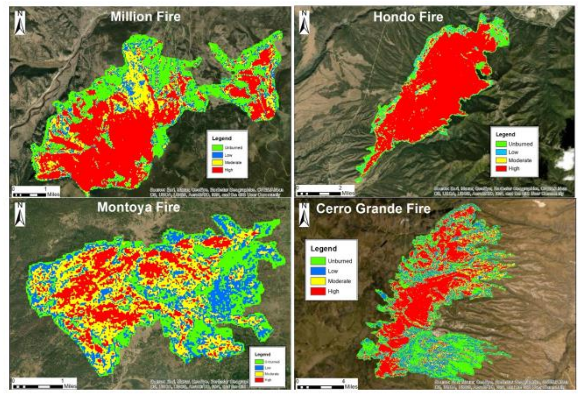
Can ETa provide a system-level measure of susceptibility to fire, impact of fire, and recovery after fire?

- Relationship of prefire ETa on burn severity?
- Relationship of burn severity on postfire ETa?
- Recovery of ETa after fire?

Conclusions:

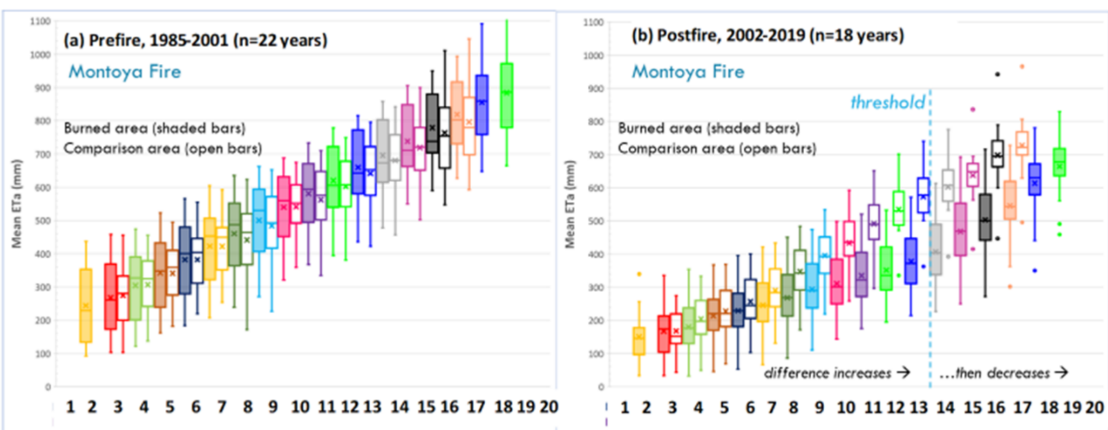
- Prefire ETa was higher in high-severity burn areas, consistent with higher fuel loads, though variability was high (many factors).
- Postfire ETa had step reduction across all burn severities in all four fire areas.
- ETa response to fire was greatest in high severity areas and decreased with lower burn severities (42 – 63% ETa decrease after high-severity fire, 24 – 44% ETa decrease after low-severity fire).
- No postfire ETa recovery after 17 – 23 years.

Burn severity
- Unburned [green]
- Low [blue]
- Moderate [yellow]
- High [red]



Fire Name	Postfire (year of fire to 2019) Change vs. Prefire Period (1985 to year before fire)				
	1: ETa Unburned to Low	2: ETa Low	3: ETa Mod.	4: ETa High	P
Million	-24%	-38%	-46%	-50%	-23%
Hondo	-18%	-24%	-33%	-42%	-4%
Montoya	-34%	-39%	-44%	-48%	-18%
Cerro Grande	-39%	-44%	-54%	-63%	-17%

This study demonstrated utility of remote-sensing ETa as system-level measure of susceptibility to fire, impact of fire, and, potentially, recovery after fire. Additional research needed to account for covariate effects of other factors: fuel, topography, weather, climate.



Prefire Period

- Paired t-test: **nsd** (p<0.05) in prefire ETa for burned vs. comparison areas across all ETa bins

Postfire Period

- **Significant difference** (paired t-test, burned vs. comparison areas), which *increased* as ETa bin increased, then *decreased* above a *threshold*
- *Threshold* ETa bin varied by fire area:
  - Montoya: ETa (bin 13) = 640-680 mm [shown above]
  - Million and Hondo: ETa (bin 17) = 800-840 mm
  - Cerro Grande: ETa (bin 18) = 840-880 mm

2021 Publications

Published

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Barnard DM, Germino MJ, Bradford JB, O'Connor RC, Andrews CM, Shriver RK. 2021. **Are climate data and drought indices good indicators of ecologically relevant soil moisture dynamics in drylands?** Ecological Indicators. https://doi.org/10.1016/j.ecolind.2021.108379

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