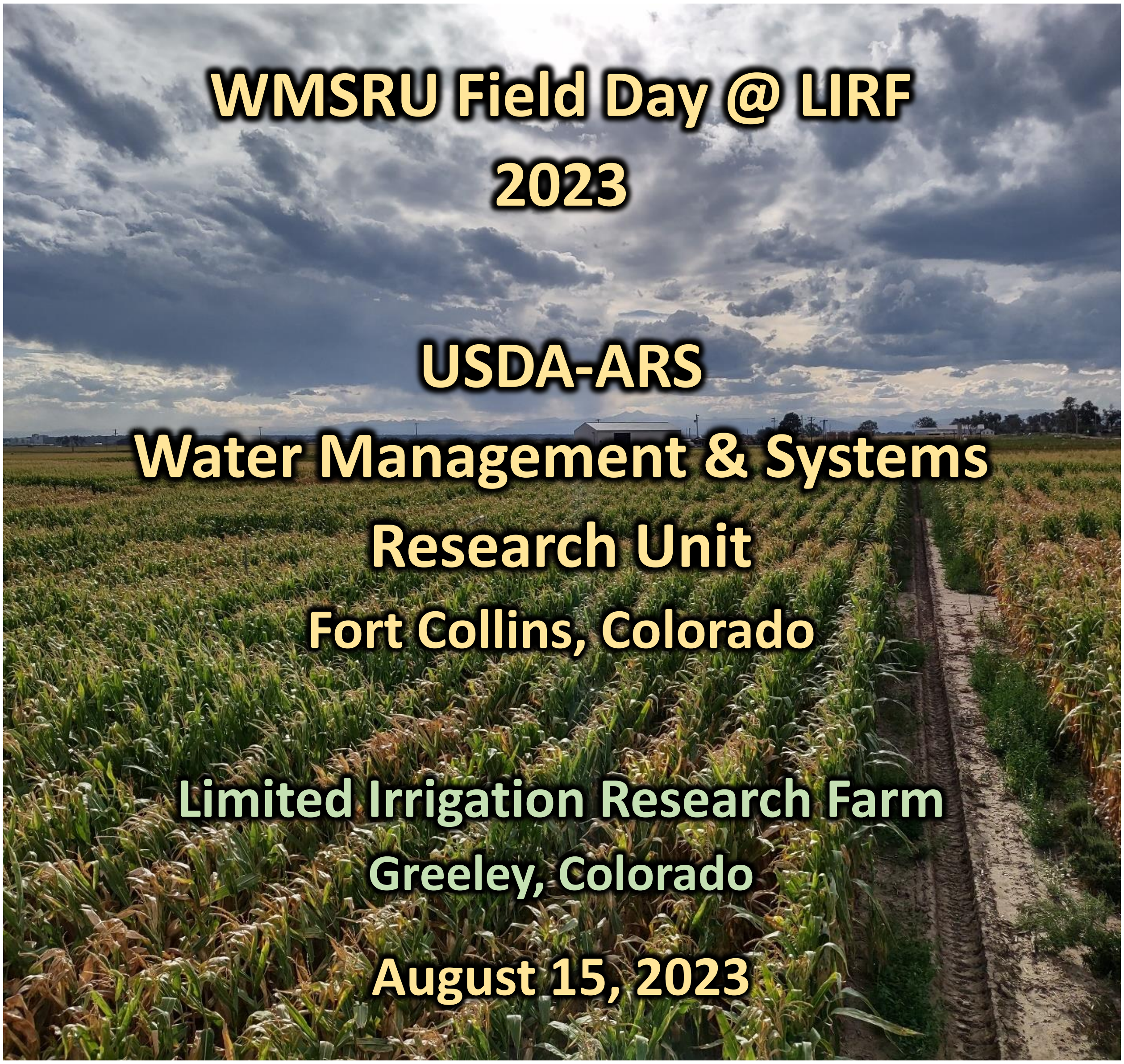

WMSRU Field Day @ LIRF
2023

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

Limited Irrigation Research Farm
Greeley, Colorado

August 15, 2023

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 improve science & technologies underpinning regional and global challenges of increasing water scarcity in agriculture.

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 water scarcity.

Our research makes advances in plant trait networks, 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. Louise Comas, Plant Physiologist
Dr. Kendall DeJonge, Agricultural Engineer/Irrigation
Dr. Sean Gleason, Plant Physiologist
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Dr. Adam Mahood, Research Ecologist
Dr. Sushant Mehan, Agrohydrology (CSU)
Dr. Sarah Tepler Drobnitch, Physiology (CSU)
Dr. Bo Stevens, Microbial Ecologist
Dr. Jared Stewart, Postdoctoral Fellow (NSF)

Seasonal Technicians, Interns

Brendan Allen, Joy Angermueller, Katie Ascough, Giovanni Borsari, Chris Brackett, Josh Brekel, Cam Caron, Carolyn Dewey, Tyler Donovan, Jude Fevrius, Jordyn Geller, Madeline Guimond, Jordan McMahon, Alex Merklein, JD Miller, Shanthini Ode, Alex Olsen-Mikitowscz, Anna Pfohl, Stephanie Polutchko, Jack Reuland, Catherine Schumak, Megan Sears, Ryan Wells

Field Day Agenda

2023 WMSRU Field Day @ LIRF
FIELD DAY THEME: How Crops Work in Semi-arid Climates
Thursday, August 15, 2023, 9:00 a.m. - 2:00 p.m.
Limited Irrigation Research Farm, Greeley, Colorado

9:00 Coffee & Donuts
In poster area. Provided by **Colorado Corn**.

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

9:30 Field tours & Demonstrations
Crop Drought Tolerance & Water Use (Sean Gleason, Brendan Allen, Stephanie Polutchko, Jared Stewart - ARS)
Irrigation Scheduling using Evapotranspiration (ET) (Kendall DeJonge, Tyler Pokoski - ARS)
Variable-rate Linear Sprinkler System (Ross Steward - ARS)
Benefits of On-farm Water Monitoring: Why & How (Jon Altenhofen - NWCD)
Crop Sensors & Measurement of Plant Water Function (Louise Comas - ARS)
Remote Sensing for Crop Production (Unmanned Aerial Vehicles & Satellites) (Huihui Zhang, Kevin Yemoto, Chris Brackett - ARS)

11:30 LUNCH
Provided by **Northern Water**.

12:00 Lunchtime Talks
Kyle Mankin (USDA-ARS): Welcome and Introductions
Sean Gleason (USDA-ARS): Research Toward Improving Plant Physiological Phenotypes
Tim Green, Adam Mahood (USDA-ARS): Systems Research & Modeling Ag Watersheds
Jon Altenhofen (Northern Water): Why study deficit irrigation? Augmented Deficit Concept
Ryan Taylor (Colorado Corn): Update
Tim Martin (CSU): TAPS – Testing Ag Performance Solutions, Year 1

1:00 CSU-ARS Plant Adaptation Round Table
Many research initiatives and directions are in the works, from screening and variety trials to phenotyping and more-intensive physiological experiments to a collaborative plant-adaptation-focused institute, and we'd like to hear if producers, agency personnel, commodity groups, and others think we're heading in the right direction.

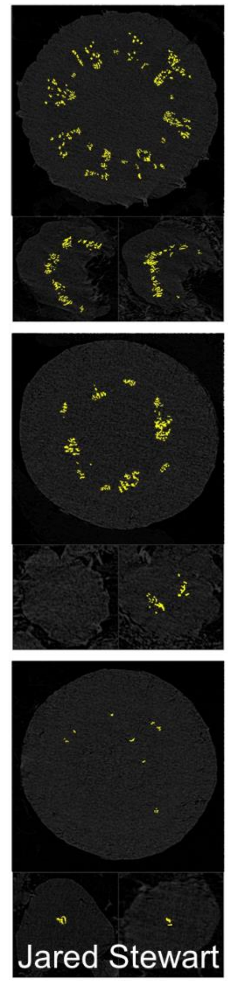
2:00 Wrap up @ LIRF

Field Tour Stop 1:
Crop Drought Tolerance & Water Use

Sean Gleason, Brendan Allen, Stephanie Polutchko, Jared Stewart

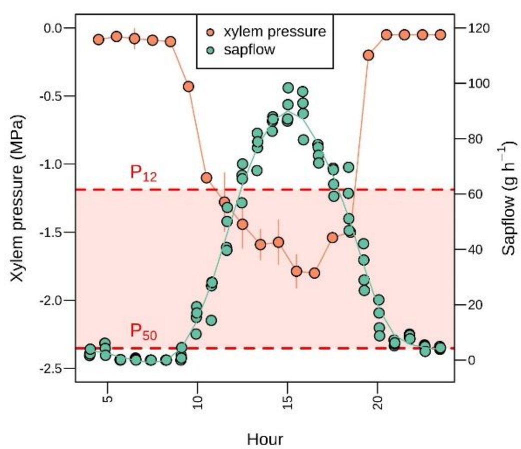
USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO

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.

Field Tour Stop 2:
Irrigation Scheduling using Evapotranspiration (ET)

Kendall DeJonge, Tyler Pokoski, Josh Brekel

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

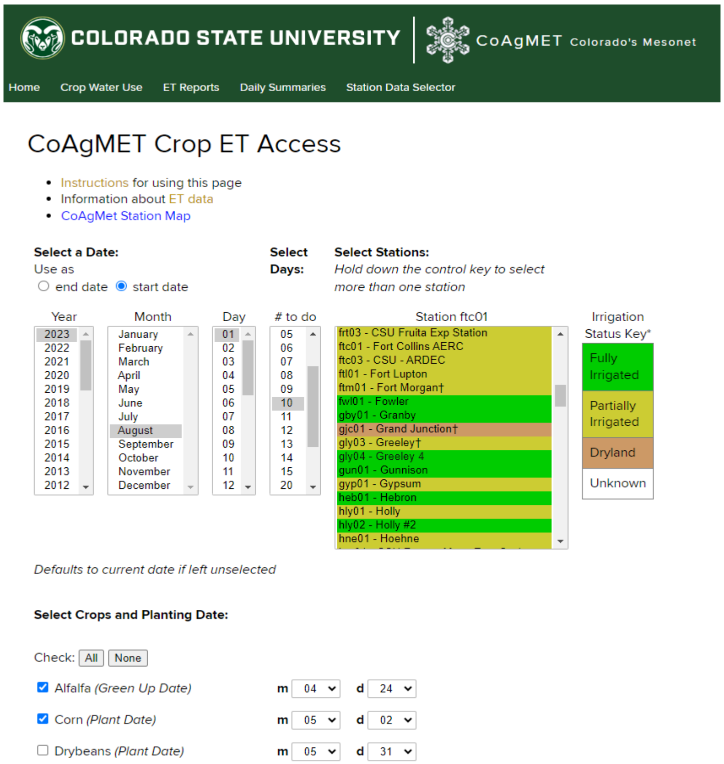
Estimating crop water use can be very valuable for water scheduling – if we can know how much water was *lost* through evapotranspiration (ET), we know how much water we need to *replace* through irrigation.

Crop ET is a dynamic process. Many rules of thumb exist, for example some say in peak corn growing conditions, such as when there is a fully grown crop in peak heat (July-August), a corn crop uses around an inch of rain every three days. That's not a bad rule, but there are tools out there for a more science-based approach.

Crop ET is determined by two main factors:

- **Environment** – using a standardized weather station from a network like CoAgMet, we measure temperature, humidity, solar radiation, and wind. Those ingredients help us calculate Reference ET (ETref, sometimes referred to as ETr or ETo), which is the ET over a consistent alfalfa or grass reference surface.
- **Crop status** – as leaves grow and intercept more light, more water is used by the crop. If there isn't available moisture in the soil, the crop will wilt, become hot, and use less water.

Tools like CoAgMet (www.coagmet.colostate.edu) are available to estimate your crop water use by choosing a nearby weather station, your crop, and planting date. All of the math is done in the background, but it can give you an estimate of how much water a healthy crop is using. Try it out! An example is below:



Crop Evapotranspiration in Inches

Date	Corn	ETr	ETo	Precip
08/01/2023	0.23	0.24	0.20	0.01
08/02/2023	0.26	0.27	0.22	0.01
08/03/2023	0.20	0.20	0.21	0.21
08/04/2023	0.24	0.25	0.21	0.00
08/05/2023	0.22	0.23	0.20	0.08
08/06/2023	0.15	0.15	0.14	0.02
08/07/2023	0.19	0.20	0.16	0.02
08/08/2023	0.22	0.22	0.19	0.00
08/09/2023	0.26	0.27	0.21	0.00
Sum	1.95	2.04	1.75	0.35
Average	0.22	0.23	0.19	0.04

These irrigation scheduling methods work well under well-watered crops. Estimating crop water use when crops are water stressed is much more complicated. Our current experiments look at several methods to estimate ET and make irrigation decisions under full and limited water. These methods include:

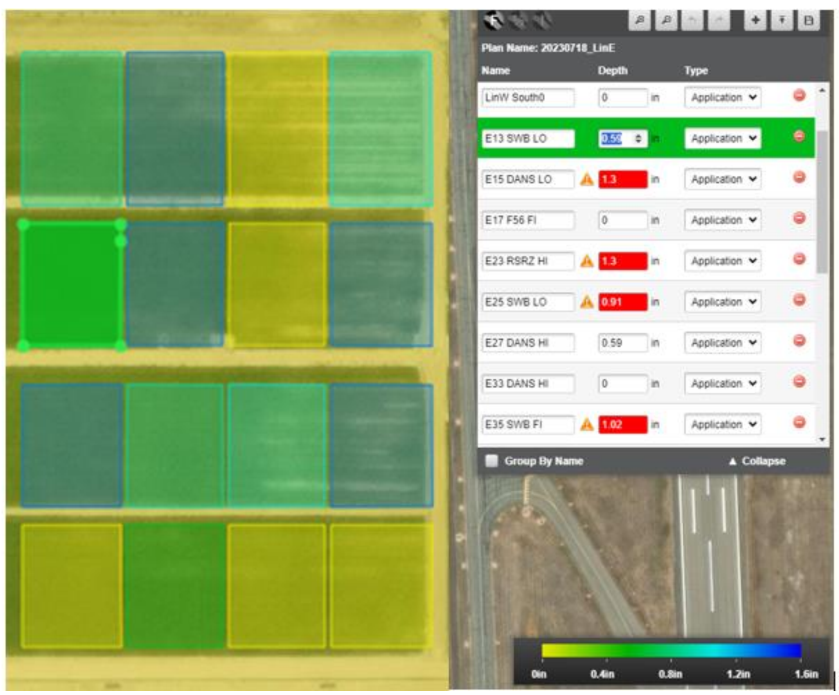
- Soil water balance (SWB), with frequent measurements of soil moisture
- Degrees above non stressed temp (DANS), with continuous canopy temperature measurement
- Remote sensing and root zone model (RSRZ), which integrates remote sensing measurements with a crop model
- Energy balance (EBAL), with an energy balance model to estimate ET
- FAO-56 crop coefficient method, which is what CoAgMet uses

Field Tour Stop 3:
Variable-rate Linear Sprinkler System

Ross Steward

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

This stop will showcase our linear variable rate irrigation (VRI) system manufactured by Lindsay Irrigation (Zimmatic). The system was installed in 2021 and has now fully replaced the previously existing surface drip irrigation system. The linear consists of 4 spans that irrigate 15 acres. The system has individually controlled nozzles on 5-ft spacing. Using FieldNet software, we can define customized irrigation zones and write prescriptions to apply specific amounts of water to each plot, depending on the needs of the experiment. This system has increased the farm flexibility and research capabilities. It is also very applicable and recognizable to farmers.



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 various 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.

Field Tour Stop 4:
Benefits of On-farm Water Monitoring: Why & How

Jon Altenhofen, PE

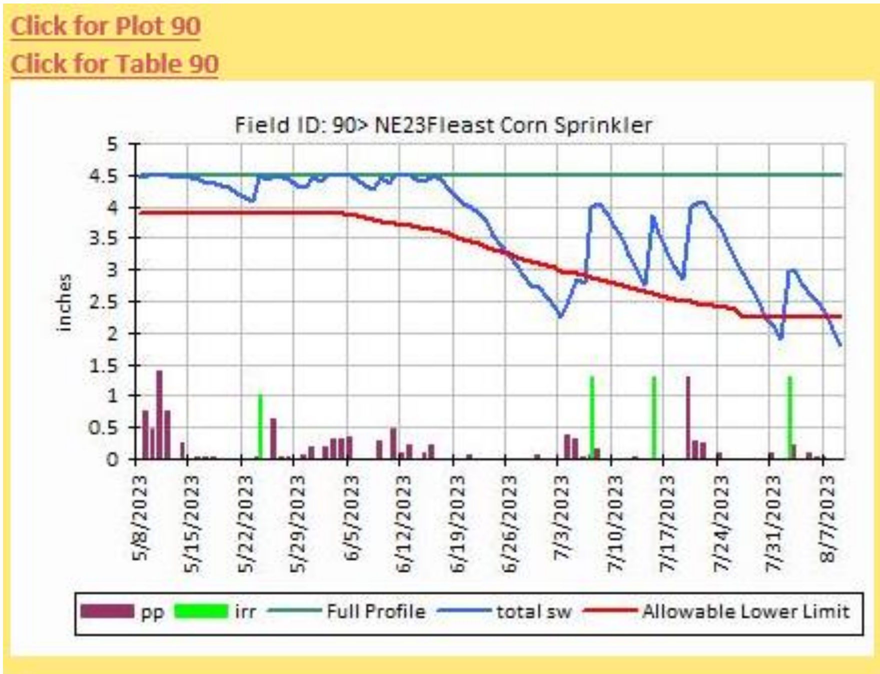
South Platte Special Project Manager

Northern Water (Northern Colorado Water Conservancy District), Berthoud, CO

jaltenhofen@northernwater.org, 970-622-2236

Monitoring of water supply and comparing to water demands (crop consumptive use, or evapotranspiration, ET) improves water efficiency and helps deal with water shortages from droughts and climate change. ET data (inches per day) is readily available from local weather stations. With the addition of in-field monitoring, demonstrated at LIRF, a site-specific ET can be determined, which can help producers determine farm specific consumptive use estimates for deficit and fully irrigated fields.

Smart phone apps/computers and websites (CSU) can give real-time access to the data as shown in water balance graph in the graph shown here (contact Jon at Northern Water if interested).



Water supply to a farm can be easily monitored by flowmeters, flumes, counting siphon tubes, ditch company deliveries, sprinkler nozzle flow rates, etc. Irrigation water supplies come with constraints for farmers, such as enough water supply (gpm/acre) to meet the ET demand (inches/day).

The table on the next page (Farm Water Supply Required to meet ET at a given Efficiency) is useful in understanding this supply constraint and making changes. Also, root zone salt build-up issues and leaching requirements (i.e., supply 15% more than ET) need water supply measurements.

FARM WATER SUPPLY REQUIRED TO MEET ET AT A GIVEN EFFICIENCY

GPM per Acre
(Based on Continuous Flowrate per Acre)

ET, inch/day	% IRRIGATION EFFICIENCY 20	30	40	50	60	70	80	90
0.05	4.7	3.1	2.4	1.9	1.6	1.3	1.2	1.0
0.10	9.4	6.3	4.7	3.8	3.1	2.7	2.4	2.1
0.15	14.1	9.4	7.1	5.7	4.7	4.0	3.5	3.1
0.20	18.9	12.6	9.4	7.5	6.3	5.4	4.7	4.2
0.25	23.6	15.7	11.8	9.4	7.9	6.7	5.9	5.2
0.30	28.3	18.9	14.1	11.3	9.4	8.1	7.1	6.3
0.35	33.0	22.0	16.5	13.2	11.0	9.4	8.2	7.3
0.40	37.7	25.1	18.9	15.1	12.6	10.8	9.4	8.4
0.45	42.4	28.3	21.2	17.0	14.1	12.1	10.6	9.4
0.50	47.1	31.4	23.6	18.9	15.7	13.5	11.8	10.5

NOTES:

(1) GPM = Gallons per minute (=cubic feet per sec X 448.8)
Above table based on continuous flowrate; if ditch delivery was for 3 out of 7 days then multiply ditch delivery rate by 3/7 to get reference continuous rate for above table.

(2) ET = EvapoTranspiration from ET weather station / ET instruments (inch/day).
Use a daily value for ET which represents a high ET day OR an average net value.

(3) % IRRIGATION APPLICATION EFFICIENCY:
Flood irrigation (furrow/border) is 30% to 70%
Sprinkler is 70% to 90%

(4) Equation for above table: GPM / Acre = (ET / .eff) * 18.8571

EXAMPLE:

(1) For a daily ET of 0.35 inch/day and an efficiency of 50%, 13.2 GPM per Acre required.
160 acres would require 2,112 GPM
1,000 GPM would supply 76 acres

If your GPM per Acre is greater than the value in the above table then you do not have to irrigate continuously.

If your GPM per Acre is less than the value in the above table then you do not have enough water and your crops will go into water stress.

Water Supply Formulas

inches = cfs x hours / acres
cfs = gpm / 450
cfs = cubic feet per sec
gpm = gallons per minute

Field Tour Stop 5:
Measurement of Crop Transpiration

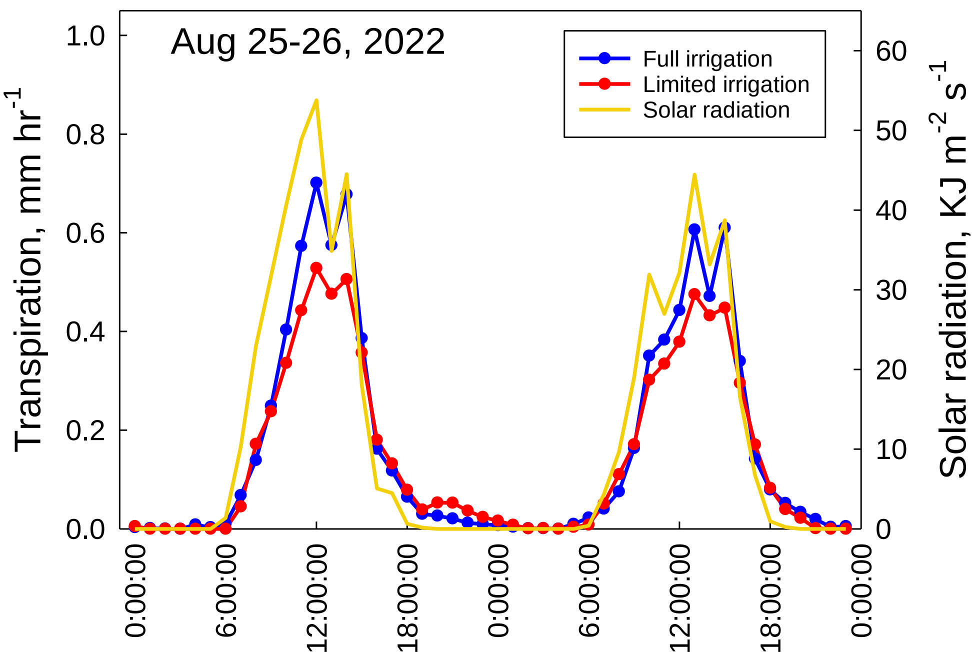
Louise Comas, Josh Wenz

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

Joseph Michaud

Colorado State University, Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, CO

Measuring sap flow (the amount of water movement through plants) tells us how much water crops are using as well as how they use it in different situations. In an ideal situation, crop water use can be estimated from weather data and 'normal' growth patterns, but nutrient management, diseases, and factors affecting crop development can alter this estimate. We can use sap flow, combined with an estimate of soil moisture, to schedule irrigation directly from plant water use. Irrigation is scheduled this way for many woody crops. At LIRF, we use measurements of sap flow to verify crop water use estimated from soil moisture dynamics or from canopy temperature measured with a variety of methods and sensors as we explore new technologies.



Additionally, we use sap flow to gain insights into plant mechanisms that can make crops more productive under limited water availability. For example, water movement through the root system often cannot keep up with the needs of the plants during peak transpiration periods. Stored water reserves in the stems are used by plants during this time. The use of stored water to support crops through these periods appears as lags in sap flow (see the offset in transpiration from the solar radiation in the graph above). We are currently exploring these lags, the dynamic use of stored water reserves in stems, and root pressure to identify and characterize new traits that can be used in breeding more productive crops for agricultural systems with limited water availability.

Field Tour Stop 6:
Remote Sensing for Crop Production (Unmanned Aerial Vehicles & Satellites)

Huihui Zhang, Kevin Yemoto, Chris Brackett

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

In the arid and semi-arid regions of the U.S., agricultural water supplies have been facing increasing uncertainty and limitations due to a changing climate, extreme droughts, diminishing aquifers, and water delivery constraints. These challenges have underscored the critical importance of optimizing irrigation practices to sustain crop growth. To achieve this, it is essential to accurately assess how crops respond to water availability and other environmental factors both spatially and over time.

Taking advantage of the advanced capabilities of Unmanned Aerial Systems (UAS), or drones, scientists at WMSRU USDA-ARS in Fort Collins, Colorado, have successfully adopted this technology to monitor dynamic changes in crop health and stress responses throughout the growing season. By doing so, they have managed to enhance crop production under limited water resources.

One particularly promising advancement in this field is the use of Solar-Induced Fluorescence (SIF) as an indicator of plant photosynthesis and eventual crop yield. Higher SIF values are indicative of increased photosynthesis and the potential for higher crop yields. In a collaborative effort involving NASA, USDA, CSU, and UC Davis, tower-based instruments are being employed to measure SIF and hyperspectral data from around 130 target areas, providing updates every 30 minutes during the growing season. These invaluable insights help us understand how quickly crops respond to variations in water stress and environmental condition.

These remote-sensing tools offer precise and timely information regarding crop health and yield potential. By utilizing this technology, farmers and agronomists are empowered to make well-informed decisions regarding irrigation strategies and allocation of resources. This significant step forward ensures food security in an increasingly resource-constrained world.

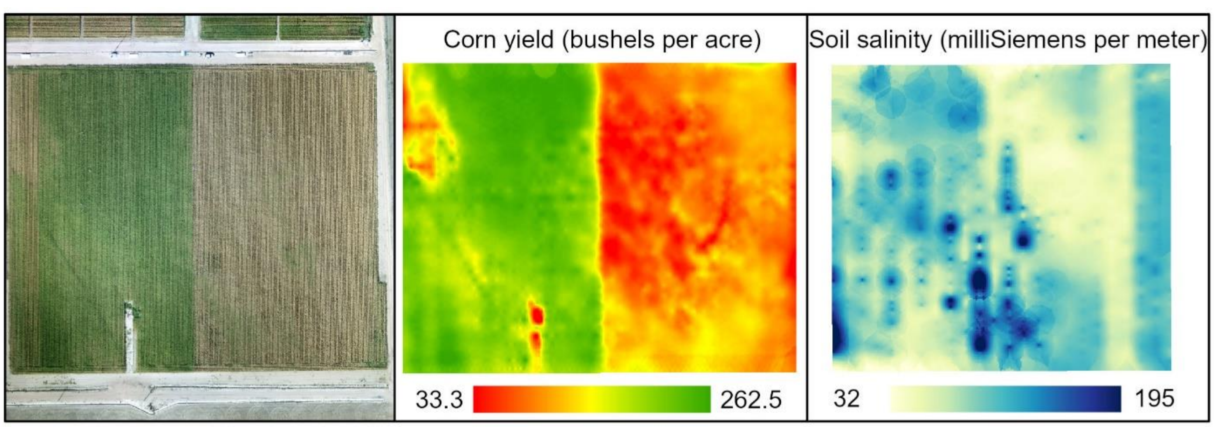


Figure 1. The images show UAV RGB (left), corn yield (center), and soil salinity distribution (right) in a field under full irrigation (left half) and deficit irrigation (right half) in 2022.

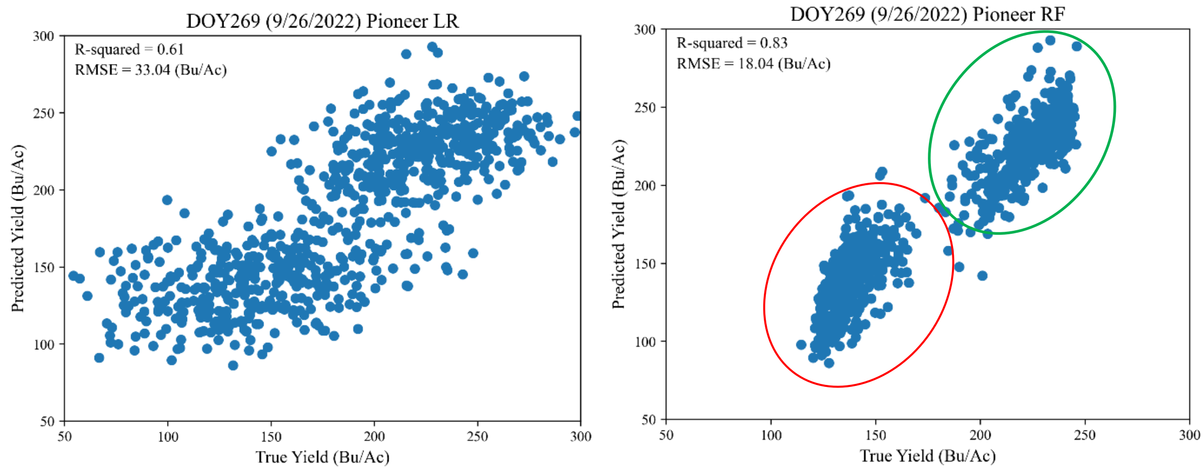


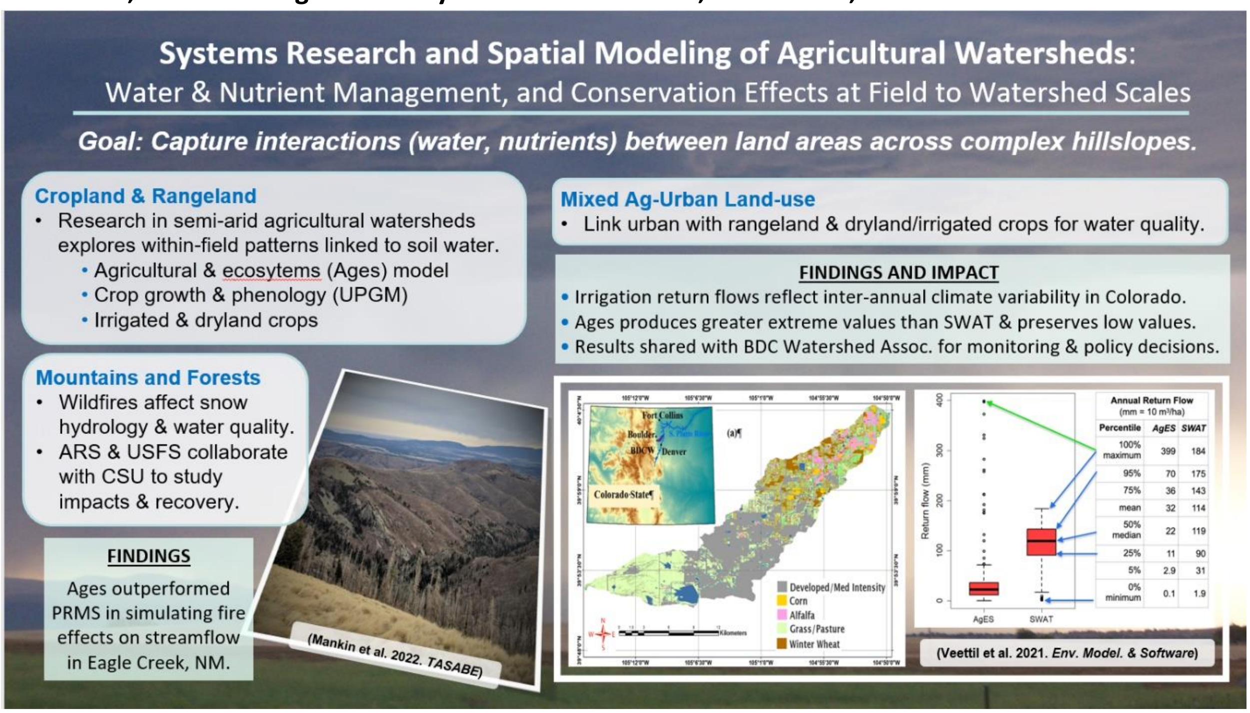
Figure 2. The measured yield vs. predicted yield using UAV reflectance data on Sept 26, 2022. The left figure shows the result using a linear regression model, and the right figure shows the result using a random forest model, which could clearly separate fully irrigated (green) and deficit irrigated treatments (red) with a higher R-squared value and smaller RMSE.

Lunch Talk 1:
Research Toward Improving Plant Physiological Phenotypes

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

Lunch Talk 2:
Systems Research & Spatial Modeling of Agricultural Watersheds

Tim Green, Rob Erskine, Adam Mahood, Dave Barnard, Kyle Mankin
USDA-ARS, Water Management & Systems Research Unit, Fort Collins, CO



- Systems researchers address water, nutrient and land management across field to watershed scales, from mountainous source-water areas to agricultural plains, from fire to farm (Barnard et al., 2023).
- Ages (version 1.0) is a modular, spatially distributed environmental model which implements hydrologic and water quality simulation components using the Java Connection Framework (JCF) and Object Modeling System (OMS) environmental modeling frameworks. Ages was formerly called AgES-W (AgroEcoSystems-Watershed) or AgES (Agricultural Ecosystems Services).
- The Ages model was developed uniquely to account for spatial process interactions between land areas from field management areas to hillslopes to large mixed-use watersheds. Researchers need an agro-ecological hydrology model that is scalable, expandable, written in open-source code, and integrated with cloud computing services, including open access tools for building model input

files, calibrating model results to match site-specific data, and analyzing results for decision or policy support.

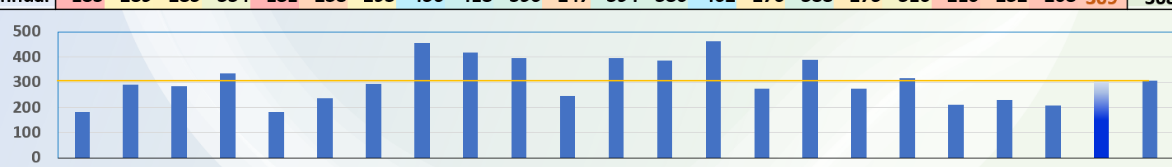
- Crop phenology in the Unified Plant Growth Model (McMaster et al., 2019; Mankin et al., submitted) within Ages improves plant growth with response to temperature and water stress.
- Ages simulates mixed land-use with point sources of N from waste-water treatment plants and non-point, but spatially explicit ag systems. Ages matched observed streamflow and N load better than SWAT, and produced realistic irrigation return flows in the Big Dry Creek Watershed, CO (Veettil et al., 2021). Results are included in the Big Dry Creek Watershed Association's stakeholder process for watershed management with membership of three municipalities.
- New research in the Rocky Mountain watersheds addresses source-waters that are strongly influenced by snow hydro-climatology, where forest fires have short-term effects on streamflow timing/quantity and quality, while longer-term effects require measurements and modeling of soil and vegetation recovery.
- New research promotes collaboration between ARS and USFS research groups in Fort Collins, CO. Wood chip ("mulching") treatments are being compared with non-mulched catchments scarred by recent wildfires. The collaboration leverages ARS expertise in watershed ecohydrology and computer simulation with USFS expertise in biogeochemistry, water quality and forest management.
- On-farm research at the Drake Farm in Colorado (2001-present) addresses dryland hydrology and spatial scaling, as detailed below.
    - Rainfall & Runoff during wheat-fallow cropping
    - Ecological Research on vegetation species after planting for Conservation Reserve Program (CRP) (Mahood et al., submitted).

Rainfall & Runoff from a Dryland Field: Measurements & Simulation

Drake Farm, Severance, CO

Monthly Precipitation (mm) 2002-2023

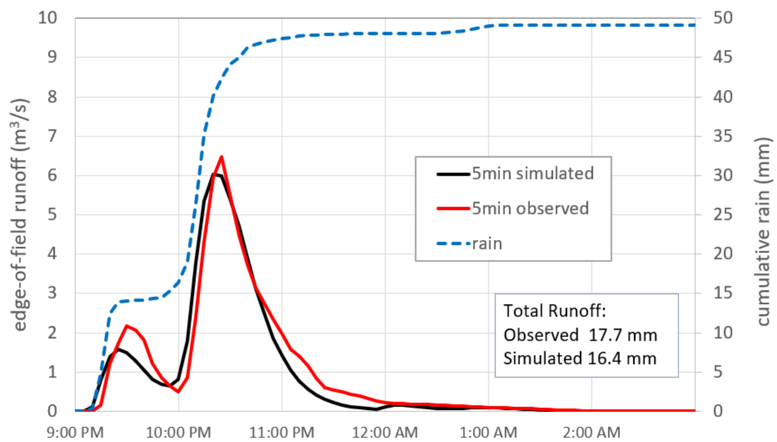
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Avg
Jan	7	1	10	5	1	7	0	0	3	2	1	9	21	3	11	19	9	6	0	3	16	15	**6**
Feb	20	7	8	3	6	2	0	0	10	11	13	7	7	16	12	7	17	3	7	8	11	7	**8**
Mar	6	45	2	33	22	37	13	7	18	8	0	15	26	5	44	29	24	46	29	23	19	24	**22**
Apr	7	**64**	28	47	9	20	17	69	**94**	26	13	70	4	56	**59**	57	16	32	21	48	2	21	**36**
May	**42**	55	33	37	26	29	41	43	79	**119**	45	47	82	***153***	46	**111**	**95**	**66**	**47**	**68**	**52**	**79**	**63**
Jun	33	43	**55**	**104**	6	11	50	83	51	35	15	17	52	51	38	4	33	44	43	21	12	69	**38**
Jul	9	4	28	6	**28**	**62**	9	51	75	94	**91**	43	**101**	57	12	32	41	21	3	17	51	63	**40**
Aug	16	44	35	14	10	37	**105**	31	37	5	0	40	24	20	23	54	8	17	11	9	3	30	**26**
Sep	23	11	53	3	16	24	37	12	2	17	40	**111**	31	2	8	35	5	25	13	11	22		**24**
Oct	11	1	24	74	20	0	12	**132**	18	56	21	21	12	54	10	26	16	15	15	7	3		**26**
Nov	10	6	8	6	9	3	2	10	24	10	4	5	16	23	4	9	10	20	8	10	12		**10**
Dec	0	8	0	1	28	7	6	18	8	12	3	9	10	22	8	4	1	21	11	8	7		**9**
Annual	**183**	**289**	**285**	**334**	**181**	**238**	**293**	**456**	**418**	**396**	**247**	**394**	**386**	**462**	**276**	**388**	**275**	**316**	**210**	**232**	**208**	**309**	**308**



Precipitation (P = Rain & Snow) measured in mm at the Drake Farm, north of Severance, CO

- Monthly P & Annual P vary substantially, within a given year & among years.
- May is a common month for maximum P, as low as 44 mm (1.7 in.), up to 153 mm (6.0 in.).
- Peak monthly P has occurred in any month from April to October.
- Winters (Dec-Feb) are typically dry with monthly P = 0 or very low in some years.
- Year-to-date P in 2023 is already greater than the average annual P of 308 mm (12 in.).
- Red box highlights a month with runoff from 49 mm (1.9 in.) of rainfall on July 12-13, 2011.

Rainfall-Runoff example



- July 12, 2011: rainfall came in two bursts (steep parts of curve) over watershed area.
- Observed runoff (red) responded with two peaks under wheat-fallow cropping.
- Ages model simulated high-resolution (5-min time step) runoff that fits measured data well.
- No runoff has been observed following establishment of CRP vegetation (2016 to present) despite equally intense rain events.
- These results demonstrate the capability of a new subdaily version of Ages to capture high-resolution runoff responses to rainfall.

Ecological research on species composition after CRP planting at the Drake Farm near Severance, CO

A field north of Severance, CO has been monitored by ARS researchers since the early 2000's. For many years it was in wheat/fallow strip rotation, and the fallow strips were successively seeded into perennial grassland as part of a Conservation Reserve Program (CRP) contract. Even though the same seed mix was used both years, ARS researchers noticed that the strips seeded on April 29,2013 appeared to have a different species composition than the strips seeded on May 1, 2014. In 2022, we conducted botanical surveys across the field, and used the wealth of soil moisture and temperature data collected at the field to link the long-term species composition outcomes to climatic conditions before seeding.

Takeaways: Land managers may use pre-seeding climate conditions to select which species to add to their seed mix and improve the probability of successful perennial establishment.

- Cool wet years may be opportunities for high-diversity mixtures.
- In hotter, drier years, it may work better to seed competitive dominant natives and slow-growing drought tolerators.
- Some years might be ideal to put the whole thing off until next year, or at least to wait for better soil moisture conditions.

Future research will expand to more sites, with more species, with the idea of getting a better sense of which species will do well in which climates. We will work with NRCS, FSA and other land management agencies in charge of perennial grass restoration to incorporate seed year climate into their seed mix species selection methodologies.

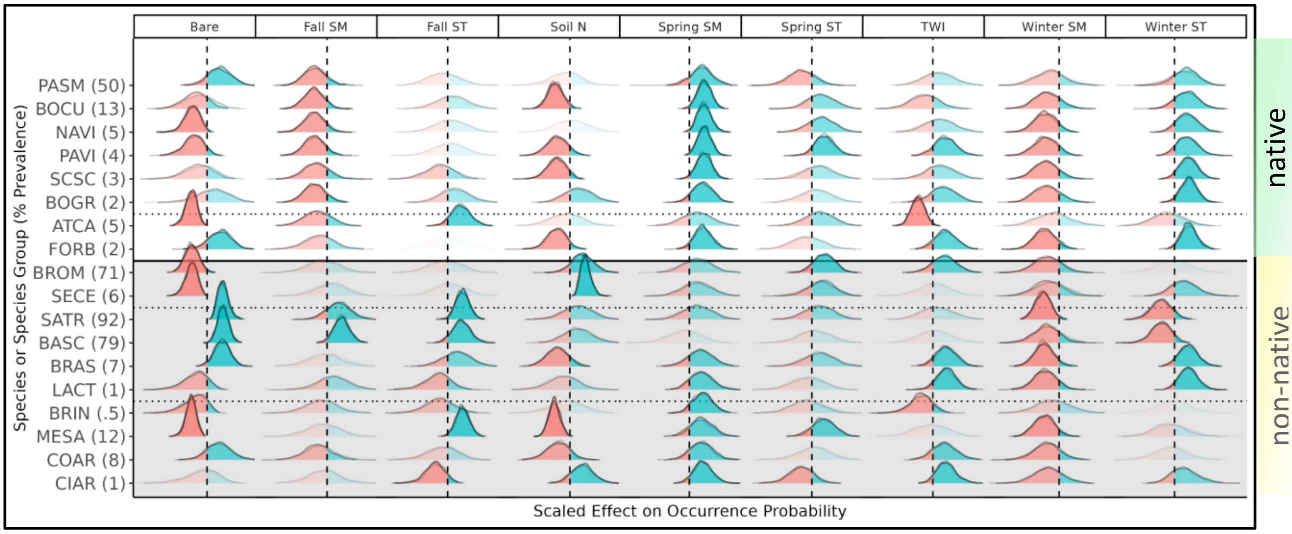


Figure*:* Long-term persistence of species as predicted by soil moisture and temperature before seeding. Each row is a species, and each column is an environmental predictor. Species above the black line are native perennials that were part of the seed mix (except FORB). Species below the line are non-natives. The number in parenthesis is the relative prevalence of each species. Histograms show positive (blue) and negative (red) influences of the environmental variable on a given species. Abbreviations: Bare = bare ground cover; SM = soil moisture; ST = soil temperature; TWI = topographic wetness index

Lunch Talk 3:
Why Study Deficit Irrigation? Augmented Deficit Concept

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Deficit irrigation strategies can be developed with the goal of maintaining yield with less ET by a good computation and clear understanding of crop water needs (ET) coupled with measuring water applied and developing a complete soil water balance. This can both help farmers respond to droughts and quantify the saved water from reduced ET that can be leased to cities through approved water supply plans and Water Court augmentation plans.

Deficit irrigation could provide an alternative to cities buying farms and drying them up permanently. However, the key aspect of transferring surface water out of a ditch system to a city is the maintenance of historic return flows (Augmented Deficit Irrigation). This maintenance is the foundation of Colorado water law and the doctrine of prior appropriation.

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 (twin-row vs 30-inch row), 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) control/recover from the water stress (irrigation frequency and amount).

The economic benefits to farmers for changing irrigation practices must be positive and incentivized – net profits should be maintained or enhanced through any leases that must be based on current $ per bushel corn prices. The economics is critical for farmer interest/participation. Economics is central to the Research, Education and Economics (REE) mission area, which houses the USDA-ARS, and is recognized by all that collaborate at the Greeley LIRF facility.

Lunch Talk 4:
Update from Colorado Corn

Ryan Taylor
Sustainability, Research and Industry Relationships Manager
Colorado Corn Council, Centennial, CO

Lunch Talk 5:
CSU TAPS - Testing Ag Performance Solutions, Year 1

Tim Martin
Irrigation Innovation Consortium (IIC) Executive Director
Colorado State University, Fort Collins, CO

Poster:
Central Great Plains Research Station History 1907-2023 – 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:
Soil Structure Stability under Different Management Practices

Maysoon Mikha, Tim Green, Kyle Mankin

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

Introduction

Land use and agriculture 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 structure stability, erodibility, nutrient dynamics, and organic carbon conservation. Soil structure stability & soil health impact soil's ability to function as a dynamic/living system that can support plant growth, promote animal health & production, sustain human needs, and preserve and/or improve air & water quality.

Why is Soil Aggregation important?

- Mediated soil physical, chemical & biological properties (Soil Health)
- Improve soil porosity, water retention, & water infiltration.
- Contributed to soil organic matter/carbon (SOM/SOC) conservation and nutrient dynamics.
- Enhance microbial activity & biodiversity.

What is Soil Structure Stability?

- Soil Structure reflects the arrangement of soil particles into soil aggregates that are cemented/bound together by soil minerals, soil organic matter, and/or microbial by-products.
- Soil aggregate stability (i.e., macroaggregates) reflects their ability to resist disintegration and withstand disruptive forces, such as wet-dry cycles, freeze-thaw succession, and rainfall events.
- Anthropogenic disruptions, such as frequent tillage, break soil macroaggregates into microaggregates that could enhance soil erosion & SOM decomposition.

Soil Aggregate Size Distribution

Disintegration of macroaggregates into microaggregates and fine particles cause:

- Decrease in soil pore continuity that reduce water infiltration and increase surface runoff & soil erosion.
- Negatively affect root penetration.
- Reduce water retention, nutrient transport, & gas exchange.

Figure 1. Soil aggregates size distribution. Shown are four macroaggregates size classes (>2, 1-2, 0.5-1, 0.25-0.5 mm diameter) and one microaggregate size class (0.053-0.25 mm diameter).

Figure 2. Historic and current soil lost through wind erosion in dryland cropping system at the Central Great Plains Region of USA.

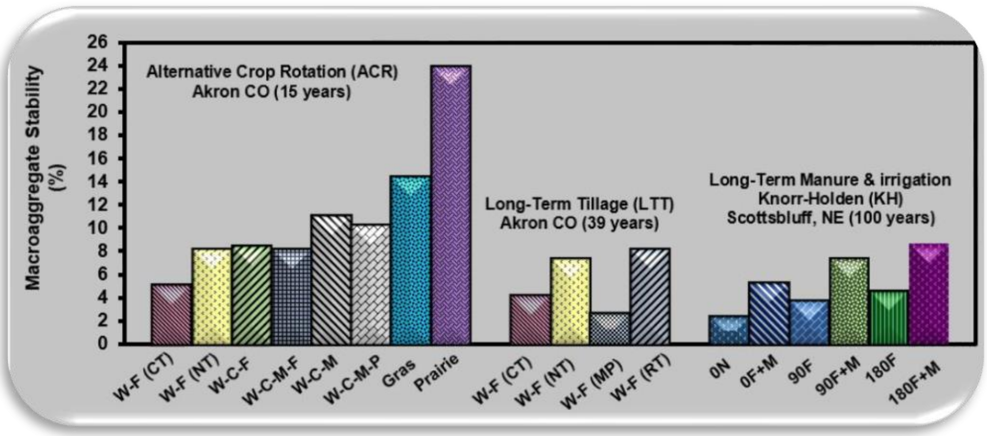

Figure 3. Soil macroaggregate stability at three locations in the Central Great Plains Region (Colorado & Nebraska).

Soil Macroaggregate Stability (%) as one of the indices of Soil Structure Stability

- At the Alternative Crop Rotation (ACR) study site, the stable macroaggregates were about 39.8% lower in grass plots compared with the prairie sites. Eliminating fallow period (W-C-M and W-C-M-P) enhanced macroaggregate stability.
- At the Long-Term Tillage (LTT) study site, macroaggregate stability decreased with increasing tillage intensity. On average, the W-F (CT) and W-F (MP) contained less macroaggregate stability by about 56% than W-F (NT) and W-F(RT).
- At the Knorr-Holden (KH) study site, the combination of synthetic fertilizer (F) with beef manure (90F+M and 180F+M) enhanced macroaggregate stability by an average of 93% compared to fertilizer alone (90F and 180F), regardless of the application rate.

Conclusions

Management decisions influenced soil macroaggregate stability and thus soil structure stability.

- In dryland cropping systems, grassland needs more than 15 years to achieve the aggregate stability level of the natural prairie site.
- Manure addition, as an organic amendment, contribute to enhance soil structure stability.
- Care needs to be taken in managing cropland to prevent soil loss, enhance nutrient dynamics, and sustain land productivity.

Poster:
Wildfire and climate change amplify knowledge gaps linking mountain source-water systems and agricultural water supply in the western United States

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Water resources from seasonal snowpack and rainfall in high elevation mountains are an essential freshwater source in many semi-arid regions. However, these areas are increasingly impacted by a changing climate and disturbance such as wildfire, resulting in streamflow volumes that are variable and difficult to predict. This difficulty is especially impactful to agricultural producers who rely on snowmelt and streamflow forecasts for crop selection and irrigation planning. The future of sustainable food production in the western United States depends on a reliable and predictable water source, but little research has been done to link together mountain source-water systems and agricultural water supply forecasting. In this paper we review how source water systems function and are impacted by disturbance and climate change, and relate these topics back to water supply management and forecasting, and on-farm decision making for agricultural production. Improved understanding of how mountains source waters and agricultural end users are linked will improve forecasting ability and improve food production.

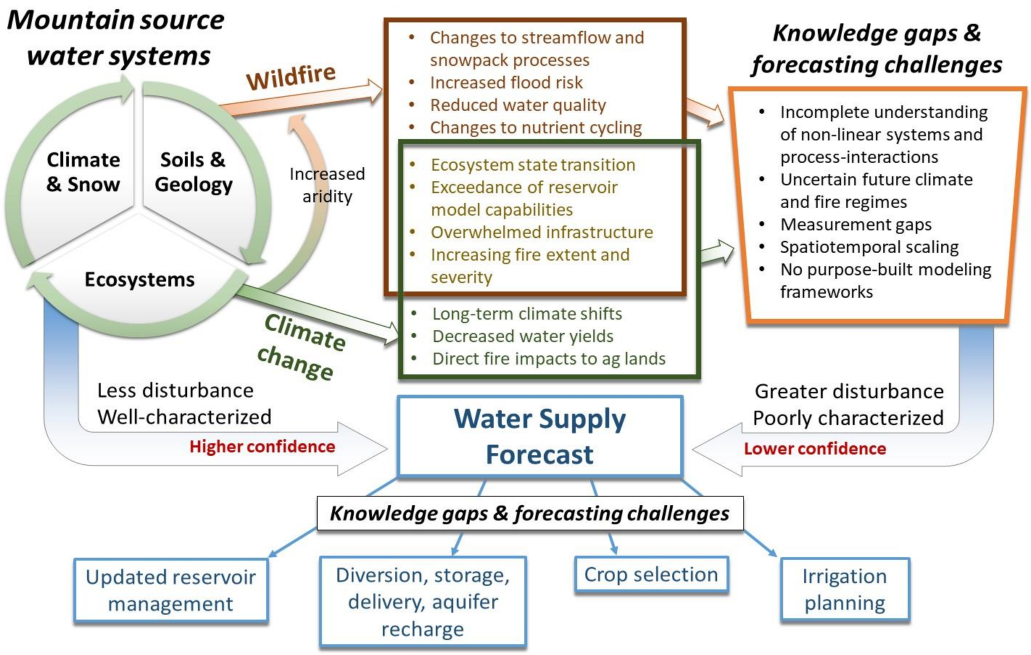

Figure 1: Conceptual diagram of mountain source water system functioning and water supply forecasting including complications due to the impacts of climate change and wildfire.

Barnard et al. (2023). Agricultural Water Management, 286, 108377. https://doi.org/10.1016/j.agwat.2023.108377

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