W5188 Annual Meeting 2025 Agenda

Dates: Jan 8-9, 2026, 8 am to 5 pm, Pacific Time

Location: George E. Brown Jr. Salinity Lab, USDA-ARS, Riverside, California

Chair: Ray Anderson Secretary: Helen Dahlke Treasurer: Thomas Harter

Virtual meeting link Zoom: https://www.zoomgov.com/my/salinitylab

Poster Presentations: Juan Acero Triana and Eric Wineteer (UC-Riverside) and Seyed Ali Azizi (Texas A&M)

AGENDA

Day 1, Thursday January 8, 2026

Day 1, Thursday, Jan 8, 2026
8:00-8:30: Continental breakfast
Morning sessions:

8:30-8:35: Welcome: Ray Anderson
8:35–10:10 Hoori Ajami, Saverio Perri, Elia Scudiero, Jirka Simunek, and Amir Verdi (UC-Riverside)
10:10–10:30 Coffee Break
10:30–11:10 Hannes Bauer and Zach Perzan (UNLV in association with DRI)
11:10-11:30 Salini Sasidharan (Oregon State) – Online presentation
11:30-11:50 Ji-Jhong Chen (Wyoming)
11:50-12:10 Tammo Steenhuis (Cornell University) – Online presentation
12:10–1:00 Lunch Break

Afternoon sessions:

1:00–1:40 Jiquan Chen and Wei Zhang (Michigan State)
1:40-2:20 Hassan Dashtian and Michael Young (U. Texas – Austin)
2:20–2:40 Coffee Break
2:40-3:00 Toby Ewing (Climate Corp.)
3:00-3:20 Joan Wu (Washington State University)
3:20-3:40 Yingxue Yu (Connecticut Ag. Experiment Station)
3:40-4:00 Kang Liang (North Dakota State University)
4:00–4:20 Pai-Feng (Victor) Teng (Minnesota) – Online presentation
4:20–4:35 Transition to Botanical Gardens

4:35-5:30 Poster Session and Reception. Presenters: Juan Acero Triana and Eric Wineteer (UC-Riverside) and Seyed Ali Azizi (Texas A&M)

5:30-7:30 Dinner

Day 2, Friday, Jan 9, 2026

8:00-8:30: Continental breakfast

Morning sessions:

8:30–8:50 Xi Zhang (U. Tennessee – Knoxville)

8:50–9:10 Behzad Ghanbarian (U. Texas – Arlington) – Online presentation

9:10-10:10 W5188 business meeting

10:10–10:30 Morning Coffee Break

10:30–11:30 Asghar Ghorbani, Scott Jones, and Morteza Sadeghi (Utah State & CA DWR)

11:30-11:50 Helen Dahlke (UC Davis)

11:50-12:10 Elnaz Ebrahimi (Iowa State University)

12:10–1:00 Lunch Break

Afternoon sessions:

1:00–1:10 Markus Flury (Journal discussion on behalf of Science Societies)

1:10-1:30 Mark Barbadillo (Oklahoma State)

1:30-1:50 Yan Jin (Delaware)

1:50-2:50 Scott Bradford, Lucia Levers, and Menberu Meles (USDA-ARS Sustainable Ag. Water Systems)

2:50-3:10 Ray Anderson and Mike Schmidt (USDA-ARS George E. Brown Jr. Salinity Laboratory

3:10-3:30 Wrap up discussion and formal meeting close

Minutes of W5188 Annual Meeting 2024
Location: George E. Brown Jr. Salinity Lab, USDA-ARS, Riverside, California

Virtual meeting link: https://www.zoomgov.com/my/salinitylab

Dates: Jan 8-9, 2026
Chair: Ray Anderson, Secretary: Helen Dahlke, Treasurer: Thomas Harter

Participants:
In-person: Markus Flury, Helen Dahlke, Scott Jones, Asghar Ghorbani, Jiri Simunek, Yan Jin, Morteza Sadeghi, Hoori Ajami, Yingxue (Charlie) Yu, Kang Liang, Joan Wu, Elnaz Ebrahimi, Jan Hopmans, Xi Zhang, Jason Goulding, Juan Sebastian Acero Triana, Hannes Bauser, Seyedali Azizi, Nan Li, Amir Verdi, Elia Scudiero, Todd Skaggs, Scott Bradford, Hassan Dashtian, Wei Zhang, Zach Perzan, Junyu Qi, Ray Anderson, Saverio Perri, Elia Scudiero

Online: Tammo Steenhuis, Salini Sasidharan, Jiquan Chen, Tiantian Zhou, Mark Anthony Barbadillo, Ji-Jhong Chen, Jose Salinas, Robert Ewing, Eric Wineteer, Bhawana Acharya, Saverio Perri, Sara Esperanza Matendo, Andrew Gray

Day 1, Jan 8, 2026, 8:30 AM-10:10 AM

Ray Anderson (UC Riverside) – Welcome and opening remarks.

Saverio Perri (UC Riverside) – Research on salinity management in dryland soils. Dryland soils can be desalinated by using phyto-assisted salt uptake combined with biomass harvest and management interventions are essential to minimize salinity outcomes over long times.

Elia Scudiero (UC Riverside) – Ground-truthing geospatial TDR soil moisture sensors with gravimetric soil-sample measurements is labor intensive and too costly. Robotic mapping of soil moisture with electromagnetic induction was tested in micro-irrigated citrus orchards and provides a cost-efficient alternative that provides similar soil moisture comparable in range and accuracy as the TDR sensor measurements themselves. They also tested near-ground passive microwave radiometry at the L-band frequency resulted in comparable measurements with an RMSE ranging from 0.041 to 0.07 m^3 m^{-3}.

Amir Verdi (UC Riverside) – Urban irrigation management. By trying to reduce irrigation water use in urban areas, there are unintended consequences of switching to drought-tolerant landscaping, including diminished aesthetics of the urban landscaping, reduced evaporative cooling, and ability to capture stormwater. They tested the effect of different irrigation treatments (20, 40, 60, 80 and 100% of ET demand) on different turf varieties and observed NDVI, LAI, canopy temperature and found only two species maintained a cool canopy under deficit irrigation and that salinity build-up is a confounding factor impacting turf response.

Jirka Simunek (UC Riverside) – Update on published research and applications of HYDRUS. Continued efforts to couple HYDRUS with MODFLOW. Recent work has focus on incorporating the overland flow algorithm KINEROS into HYDRUS. A second effort is dynamic plant uptake by coupling HYDRUS with SUGAR to simulate carbohydrate uptake and development in plants. Several updates to the model code were presented including the HyPar module to include PFAS, particle transport for microplastics, updated color palettes and HYDRUS log files.

Hoori Ajami (UC Riverside) – Integrating observations and models to characterize groundwater recharge processes in mountain-valley aquifer systems. Conducted streamflow recession analysis to determine mountain block recharge contributions to streamflow. They are now using the same recession analysis methods on soil moisture data. Collaborated with Jirka Simunek on coupling HYDRUS and MODFLOW and found that the coupled model runs 5-times faster than PARFLOW.

Day 1, Jan 8, 2026, 10:30 AM-12:10 PM

Hannes Bauer (University of Nevada, Las Vegas) – Hydrologic scaling challenge: Presented hydrologic flow and transport process understanding at the hillslope scale. Using data from the Arizona Biosphere 2 Landscape Evolution Observatory, which provides very controlled conditions (11 m wide, 30 m long and 1 m deep hillslopes). Investigates the state-dependence of hydraulic properties across scales. Soil moisture sensor that are installed in a 2 by 1 m grid in the hillslope indicate that the sensor variability (the variation between individual sensors) is greater than the heterogeneity in soil properties across the hillslope.

Zach Perzan (University of Nevada, Las Vegas in association with Desert Research Institute) – presents simulations of heterogeneity in the subsurface on managed aquifer recharge. Saturated zone storage efficiency (increase ins storage divided by applied water) decreases over time and recharge efficiency increases over time (less water goes to storage and more is moved through the unsaturated zone). In the second part of the presentation, he presented on solute cycling in a semi-arid floodplain and underlying aquifer. Conducted blue dye experiments (55 cm of applied water) and observed macropore flow and limited interaction of the recharge water with the soil matrix and evaporites in the soil. Developed a model to simulate evaporite formation. Simulations did not match pore water samples taken at the site. They concluded that the difference in pore water chemistry is the result of how wetting of the profile unfolds. A bottomup (e.g. rising water table) wetting event which is not dominated by macropore flow and therefore results in more interaction with the soil matrix.

Salini Sasidharan (Oregon State University) – Online presentation. Food-energy-water-data-ecology nexus research. Worked on establishing a MAR field site near Oregon State University. Has installed several drywells and is using potable water for recharge. A HYDRUS-2D model is being developed to simulate the recharge process. Another research area is to investigate the use of solar panel runoff for recharge. The team has installed a solar system and runoff collection system and is analyzing the water quality of the runoff and potential treatment systems before use for recharge. They also investigated different back-flushing practices to maintain recharge capacity of the drywell. Her team is also currently investigating the source of groundwater nitrate contamination using bacterial, isotope and chemical data from well water samples, land use data, and predictive transport models.

Ji-Jhong Chen (University of Wyoming) – Evaluate sensor-based irrigation strategies to sustain crop growth in turface (calcined clay granules). This research is performed under a NASA EPSCoR project that is trying to investigate how to grow plants on other planets using the locally-available mineral soil. The research is assessing water and nutrient availability of these porous media. They conducted laboratory experiments using different particle sizes (coarse, fine) and water contents (45%, 50%, 55%, 65%) while comparing containers with and without plants. If discharge or irrigation water is prevented from the pots, over time salinity and ion toxicity increases.

Tammo Steenhuis (Cornell University) – Online presentation. Unstable wetting fronts. Unstable finger flow occurs in sandy and water-repellent soils. He first talked about unstable vs. stable wetting fronts. Dry sand developed clear fingers (macropore flow paths) in contrast to moist sand (4% water content, near field capacity) which developed a slow-moving wetting front. Pressure and water content regimes in both systems behave the opposite way: in the sand near field capacity the pressure is high at the beginning of the wetting event and water content is low, while in the dry sand the pressure is near zero and water content is high. The working hypothesis is that the matric potential at the wetting front is discontinuous, water flows through one pore at a time and results in high velocities in an unstable wetting front that increases contact angles. Larger contact angles are related to increased pressure at the wetting front (Laplace equation), which results in finger flow. Water meniscus becomes convex in an unstable wetting front while it is concave in a stable wetting front and can be predicted by the Baver-Hoffman equation. They conducted pore-scale lab experiments to observe the velocity of the wetting front. The wetting front moves intermittent (not smoothly) and progresses one pore at a time (it looks like cohesion of water molecules and adhesion forces compete with each other until cohesion is overcome). Darcy's law can be used to model flow behind the wetting front but not to predict the wetting front.

Day 1, Jan 8, 2026, 1:00 PM - 2:20 PM

Jiquan Chen (Michigan State University) – AI-based frameworks for crop management. Existing model has frustrating limitations & discouraging results. There is limited understanding of how carbon uptake in forests changes after wildfire disturbance. Ecosystems are far too complex for us to fully understand their dynamics. Eddy Covariance flux towers measure over 80 variables they collect at high resolution but often we don't use those data and often only report CO_2, latent and sensible heat flux, ET, temperature, PAR. Most EC flux tower station violate the fetch assumption, meaning they don't have a uniform, flat surface for 500 m in every direction around them. Using ML or AI-based spatiotemporal fusion models they could achieve R^2-values of 0.86 or higher. We need to go back to our foundation of theoretics. AI4Yields predicts yields for any location and crop using high-resolution geospatial and temporal data on soils, management practices, climate etc.

Wei Zhang (Michigan State University) – Research on environmental pollution. Toxic metals in soils and crops are a public health risk. Presentation contained a call to action to measure metals and metallomics in soils to better understand their transport into plants. Research was recently expanded to organic pollutants. They tested some soil amendments such as biochar and its impact on metal uptake by crops.

Hassan Dashtian (U. Texas – Austin) – Updates on the Texas soil observation network (TxSON) and life cycle assessment. The Texas soil moisture network is now 10 years old, and most soil moisture sensors are still working reliably. Data is used for comparison and training of the SMAP satellite, which measures soil moisture from a satellite. They have a new collaboration with NASA on the development of a new satellite (NISAR soil moisture data). The new satellite will also be able to detect CO_2 emissions from abandoned wells. They conducted injection experiments of hot water into the subsurface. Each injection triggered the release of CO_2 from nearby wells. The data was used to develop a ML model to predict CO_2 leakage from wells. Physics-informed neural networks to predict deep vadose zone moisture.

Michael Young (U. Texas – Austin) – Comparing life-cycle environmental impacts and costs of electricity generation systems. Analysis goes from cradle to grave – handles various types of environmental impacts on air, land and water. Solar power generation has about one-third of the power generated by a gas power plant, so you need to triple the solar production in order to match the gas-sourced electricity supply due to variability in solar radiation availability (e.g. clouds, seasons). Fossil fuel-based electricity production has about 0.5 t of CO_2 equivalent per 1 Mega Watt Hour without carbon capture. With carbon capture it reduces to about 0.17 t. Green energy sources are much, much lower than that (< 0.03 t per MWHr). The land footprint is higher for solar than CCGT (coal combustion) and wind. For every energy technology there is some environmental impact. For solar panel and battery development metals are being released into the environment. The more mixes of different energy sources are being used in the grid, the more expensive the energy will be there. The grid operator will add the environmental cost and grid operation cost to the consumer cost.

Joan Wu (Washington State University) – Presented on the continuing work on urban stormwater management and water erosion in the inland pacific northwest. Urban stormwater management focuses on green stormwater initiatives. Current placement is based on developer convenience rather than an optimal hydrologic location. Joan presented a flow chart where the hydrologic suitability index (HSI) is combined with environmental justice in three scenarios: 1) base (no change), 2) GSI placement considering HSI and 3) an extended scenario that includes environmental justice. Trees are a preferred GSI solution. She also presented an erosion study on the Palouse focused on conservation tillage with focus on erosion hot spots.

Yingxue Yu (Connecticut Ag. Experiment Station) – Micro- and nano-plastic transport. Proteins, lipids and organic matter in soil can all interact with nano- and micro-plastics. They research how the eco-corona affects the aggregation of nanoplastics. They use a bio-degradable polymers commonly used in agricultural settings (PBAT nanoplastics). The critical coagulation concentration increases depending on the electrolyte concentration of the soil solution. In other words, microplastics aggregate in soil solution if the electrolyte concentration of the soil solution increases.

Kang Liang (North Dakota State University) – Kang presented on tile drainage-salinity linkages in crop productivity. They are researching different salinity levels on crop yield along with other soil and nutrient management practices.

Pai-Feng (Victor) Teng (University of Minnesota, Twin Cities) – He works with the Upper Mississippi River Basin Association (UMRBA) to improve water management so that hydrologic flow in the upper basin can be maintained for navigation. They are interested in identifying the minimum streamflow threshold needed to support navigation. He is also assessing the impact of diversions and consumptive uses on locks and dams (i.e. sluice) along the river.

Markus Flury (Editor in chief of Soil Science Society of America journal) – VZJ and Agricultural & Env. Letters are open access journals. Open Access costs are comparable to AGU journals, HESS (EGU) and Interpore (new journal by InterPore society). Journal publications are the biggest source of income for societies. ACS journals are ES&T, ES&T Letters, Agricultural Science & Technology. Societies are also publishing newsletters such as EOS, C&EN or CSA News. Finland has erased several journals (MDPI journals and some Frontiers journals) because of irregularities with peer-review process. All journals have AI policies now. AI should only be used to improve readability or language. No other uses are allowed. Markus provided several examples of AI use statements that clearly define what AI tool was used for what purpose (e.g. data analysis, language) in the manuscript.

Day 2, Jan 9, 2026, 8:30 AM-10:10 AM

Xi Zhang (University of Tennessee – Knoxville) – Soil-bio-physical processes in the subsurface. Studies soil structure evolution and its links to ecosystem services. They research how including cover cropping into no tillage will influence soil structure. Different root systems are studies on hey they influence the pore space and water flux. Another focus is using bio-tillage (tap root systems of certain crops) to penetrate and open up hardpans in some soils in the southeast. Tap roots are considered a form of biological tillage of the soil. They are also testing the use of cover crops (e.g. cereal rye) in the foot slope areas will evaporate water from wet soils and improve yield potential of those locations.

Behzad Ghanbarian (University of Texas – Arlington) – Online presentation. Estimating soil water retention curves from particle size distribution. There are theoretical models and fractal theory models that are being used to estimate particle size distributions. Empirical models include pedotransfer functions such as Rosetta. He proposes to use physics-based machine learning methods with deep learning to predict soil water retention curves from particle distributions. Used over 660 soil samples from different countries. Split data into 80% for training and 20% for testing. Physics-informed neural network (PINN) is a 1D convolutional neural network that enforces soil hydraulic consistency. They use saturated water content and organic matter as input feature and the soil water retention curve is the output. They have over-estimation on the lower water content and underestimation on the higher water content. They found that using the bulk density (with 2.65 g/cm^3) has resulted in water retention curves were too far off from observed data. They also assume a 0° contact angle. Markus proposed to do some uncertainty analysis on the role of the contact angle on the results. He also mentioned that most retention curves are produced with pressure plates in the lab and those pressure plates do not perform well at high retention.

W5188 business meeting –
New attendees: Jason Goulding (UC Riverside), Jonathan Oti (Oregon State), Juan Acero Triana (Oregon State), Ruan Gomes (Oregon State), Sara Esperanza Matendo (visiting scholar, technical university of Madrid, Spain), Mark Barbadillo (Oklahoma State U.), Junyu Qi (University of Maryland), Seyed Ali Azizi (Texas A&M University), Bhawana Acharya (University of California Riverside)

Update on the budget was brief since the treasurer was absent.
Zach Perzan (University of Nevada, Las Vegas) was elected as incoming secretary.
W5188 has not been assigned a new representative or liaison at USDA.

As chair, we need to request authorization for the annual meeting well in advance and we have done this early in 2025 (August).
Meeting will be in Davis, CA on either January 4-5 or January 5-6, 2027. Helen will decide based on room availability.
Wei suggested to raise the registration fee to cover an invited speaker.
Suggestion to add a block for open discussion of topics of interest.
Toby proposes that speakers focused rather on one topic than multiple projects in their presentations and end their presentation with a controversial statement. Talks should also gear more towards the objectives of the group.

Scott Jones (Utah State University) – Update on the NASA project (now in its 5th year) to irrigate a plant bed to grow plants (called the root module) in space. They have mostly worked on the irrigation system that consists of a C650 water content, EC and temp sensor and a TEROS 1 back-up sensor. The System is a fertigation system that delivers water and nutrients. They use hardware that has been used in space before. They are trying to qualify peat as a growth medium. Air buildup in the system has prevented water delivery to certain parts of the root module. They tested a system that consist of a stainless-steel rod insight the porous ceramic cup into which small) 0.57-0.84 mm holes are drilled every 5 cm to allow draining the air but maintaining enough water pressure. The smallest orifice size (0.57 mm) gave the best performance to discharge air and maintain pressure at low flow rates.

Asghar Ghorbani (Utah State University) – New soil water retention and conductivity function. Showed comparison of Peters, Durner and Iden (PDI) soil water retention model versus the extended van Genuchten-Mualem Model. They solve the non-capillary water retention part for h but are unsure whether this is physically valid or not. The new approach focuses on predicting unsaturated hydraulic conductivity. The soil water capacity curves calculated from soil water characteristic curves obtained with the PDI model results in negative values while the Extended Van Genuchten-Mualem model is always resulting in positive values. The extended van Genuchten-Mualem model uses the same parameters as the original model but has one more constant added ($h_0 = 10^7$ cm).

Morteza Sadeghi (California Department of Water Resources) – New soil solution to single depth moisture flux relationship. Darcian flux relationship connects darcy flow to soil moisture but it needs measurements at two depths to calculate a gradient. But the SMAP satellite images only give a single soil moisture value. Large scale groundwater models don’t want to solve Richards equation iteratively so they use either a gravitational modeling approach or a kinematic wave equation (unsaturated zone flow package). SM2RAIN (Brocca et al. 2014) assuming flux is a power function of soil moisture (or unsaturated K). He modified the SM2RAIN model to expand it with two more terms that include Kirchhoff and Laplace transformations of the

Richards equation. The extended model works better for fine-textured soils where you sometimes have upward flow. It was also really well in clay.

Helen Dahlke (UC Davis) – Helen presented on water and nitrogen dynamics under managed aquifer recharge. MAR is increasingly critical in California. Groundwater nitrate, chronic lowering of water tables, and land subsidence could benefit from intentional recharge of groundwater. MAR needs large areas to capture large volumes from flood events. Research was conducted at Terranova Ranch. Unsurprisingly sandiest soil has the fastest nitrate leaching. They modeled nitrogen and water balance changes for different MAR scenarios including different durations (8-20 days), timings (Feb, Mar, Apr) and intermittent flooding. For early flooding, nitrate leaching was compensated by increased N mineralization. Intermittent flooding resulted in more leaching due to cycles of increased mineralization and subsequent leaching in repeated flood cycles. MAR creates long-term carbon loss that can be compensated by adding compost and cover crops.

Elnaz Ebrahimi and **Bob Horton** (Iowa State University) – Bob provided two slides on determining soil water fluxes without the need for Darcy, Buckingham, or Richards equation. Elnaz presented simulations of soil loss with or without the introduction of cover crops (2008-2017) on agricultural land. She looked at focusing cover cropping on lands with >10% slope, >6% slope, 2% slope. She also showed images of how soil compaction is influencing root penetration and root growth in soil for Durum wheat. Another topic she is working on is soil compaction from field traffic. They are investigating this for different slope positions (top of the hill, backslope, toe slopes).

Afternoon sessions:

Toby Ewing (Climate Corp. Bayer) – Used a Brooks-Corey classical pore size distribution and added noise to the curve at different suctions (h=0.1, 5, 10, 20, 33, 50, 100 to 5000). He pleas that when you report water retention curve, please report the soil core height. If we have measurements of water retention and sample height, we can obtain parameters for the water retention curve models such as Brooks & Corey. Getting the θ_c value of the model is very difficult, especially for low-tension values. There is a network effect in the soil sample that affects the true pore size distribution. Scott Jones asked about hysteresis effects and determining a minimum height required for soil sampling to determine pore size distributions and water retention.

Mark Barbadillo (Oklahoma State) – obtaining improved unsaturated hydraulic conductivity and drainage estimates using Rosetta1 water retention parameters. Oklahoma Mesonet uses soil samples and properties from 60 cm depth. They estimate the unsaturated hydraulic conductivity from van Genuchten parameters. Rosetta was upgraded to Python version, which also introduced changes to parameter optimization. The code changes introduced in the Rosetta3 version has resulted in changes in the water content estimates compared to Rosetta1 version. The most obvious change was that there is a decrease in K(θ) towards the wet end and Rosetta 3 is less sensitive to low suction values (predicts lower K(θ) values than previous version). Rosetta3 estimates of K compare well to recharge rates reported for major aquifers in OK.

Yan Jin (University of Delaware) – Delaware has the lowest average elevation of any states in the US. Sea level rise in Delaware is twice as fast as in any other part. They have collected stable water isotope data from coastal marsh sites and calculated the evaporative effect index for the meteoric water line. This help understand sources of water at different seasons of the year. They also investigate the availability of carbon in soil profiles to 2 m depth and how actively this carbon is used in biogeochemical processes. Yan also had a conversation with AI on the topic of: *For a long time, soil physics treated preferential flow as a nuisance because it violated continuum assumptions and prevented simple quantification of water flow. But from an ecosystem perspective, heterogeneity is not a defect — it is a design feature. Preferential flow creates hydraulic connectivity, biogeochemical niche diversity, and deep water access that enhance ecosystem resilience to droughts, floods, and nutrient stress. The challenge now is not eliminating heterogeneity, but learning how to manage and model it.*

Scott Bradford, **Lucia Levers**, and **Menberu Meles** (USDA-ARS Sustainable Ag. Water Systems) – Lucia Levers is working on hydro-economic modeling and econ-ecological analyses. She is using regional programming models that account for biophysical and economic inputs and predict crop production and profits. She has conducted valuation surveys to assess willingness of farmers to accept changes for the common good (e.g. reduction in water use). She also works on cost-benefit estimation of soil health practices, pollinators across spatial scales. Menberu presented on why hillslopes matter in groundwater sustainability (collaborative study with Hoori Ajami and Jason Goulding). Expand managed aquifer recharge to non-flat areas such as hillslopes using a watershed model. Modeling shows that recharged water has extremely long residence times to reach valley aquifer (>2 years up to 8000 years). They are considering collecting hillslope runoff along roadside ditches and recharge that water in small infiltration basins. They used a MIKE-SHE model to explore different MAR and pumping scenarios (ASR and infiltration basins) in the flat valley part and hillslope areas. Scott provided an overview on the activities of the USDA ARS SAWS unit. He presented numerical modeling results of different lengths and diameters of drywells, installed into the unsaturated zone for recharge. In another simulation study they have investigated different clogging behaviors of clay particles in sources water used in drywell recharge and how they impact clogging of the well. Different clay concentrations trigger different clogging behaviors that depends on chemistry, attachment and concentration. They have conducted time-lapse electrical resistivity tomography measurements in five drywells installed in the Central Valley, CA to evaluate the recharge efficacy of the drywells. They are also developing a more computationally-efficient watershed model by combining KINEROS, HYDRUS and MODFLOW.

Ray Anderson and Mike Schmidt (USDA-ARS George E. Brown Jr. Salinity Laboratory) – Ray presented on integrating soil moisture data into satellite-based evapotranspiration estimates. He is using the BAITSSS model (model that predicts ET and needed irrigation amount over time). They are comparing SSURGO, POLARIS soil models with BAITSS to predict irrigation needs in Yuma, AZ. AWC was consistently smaller in SSURGO than in POLARIS. As a result, predicted irrigation frequency was much higher in the SSURGO-based model than the POLARIS model. Likewise, ET estimates differed due to differences in available water capacity between SSURGO and POLARIS. Mike's research is focused on soil organic matter accumulation in a vineyard soil. How is regenerative soil management impact the dynamics of different soil organic matter fractions/pools in soils. They tested a combination of compost, fertigation and foliars, no tillage and cover cropping in comparison to conventional farming. They looked at POM, MAOM, and DOM fractions, soil pH, total N and C, texture, effective cation exchange capacity and conducted DRIFTS (Diffuse Reflectance Infrared Fourier Transform Spectroscopy). MAOM and DOM fractions are higher in regenerative soils. POM fraction was similar between both soils, indicating modest differences in soil structure between the two management regimes.

Meeting adjourned at 3:30 pm

Accomplishments

Short-term outcomes

University of California, Riverside (Hoori Ajami)

- Contributed to developing a computationally efficient hydrologic model at a watershed scale
- Contributed to characterizing preferential flow paths using high resolution soil moisture sensor data
- Contributed to understanding of how roots influence subsurface structure
- Contributed to understanding of surface water-groundwater interactions due to droughts
- Characterized mountain system recharge processes to valley aquifers in southern Sierra Nevada

University of California, Riverside (Jirka Šimůnek)

The HYDRUS models are continually updated based on the basic research conducted by the W5188 group. The HYDRUS-1D model was downloaded more than 10,000 times in 2025, and over 60,000 HYDRUS users from all over the world registered on the HYDRUS website. We continue to support all these HYDRUS users from the USA and around the world on the HYDRUS website through various tools, such as Discussion forums and FAQ sections, and by continuously updating and expanding the library of HYDRUS projects.

Finally, in 2025, we offered four short courses on the use of HYDRUS models in Europe, North America, China, and the Middle East. Over 150 students participated in these short courses.

University of California, Davis (Thomas Harter)

- Measured water and nitrogen fluxes in our instrumented 140-acre field-site with three monitoring networks for water and nitrogen: landscape (irrigation and fertilizer application monitoring, ET, harvest monitoring); vadose zone monitoring (soil water tension, soil water content, soil water solution.
- Demonstrated the variability in deep vadose zone properties and resulting variability in recharge front behavior under AgMAR.
- Analyzed shortcomings of incomplete Butte Valley Groundwater Sustainability Plan and developed alternative approaches to completing the plan
- Analyzed indicators within the functional flow framework to predict environmental instream flows and developed a functional flows forecasting tool for an intermontane, irrigated agricultural basin (Scott Valley, California) as a decision-making tool for surface water and groundwater management

- Monitored and evaluated deep vadose zone monitoring system in an irrigated tomato-field crop rotation for improved understanding of water and nitrogen fluxes across the deep vadose zone
- Engaged with social scientists to improve understanding of stakeholder perceptions with respect to use of models as decision-support tools in groundwater management
- Conducted numerous outreach and extension meetings to educate a wide range of audience members on groundwater issues.

University of California, Davis (Majdi Abou Najm)

A lot of focus was given to outreach and building pilot experiments in agrivoltaics which made large impact in terms of bringing attention and interest in this new and promising technology. This year, I also participated in numerous talks, presentations, and outreach meetings with different stakeholders. Furthermore, and in collaboration with the German-American Chamber of Commerce, we built on our success over the past 2 years and launched California's third conference on Agrivoltaics, which was very well received and attended (attendance around 150) with representations from growers, to policy, energy and industry groups. The conference worked as a catalyst bringing all those groups together and help each group connect with other groups. Also, I have worked with policy groups including California Climate and Agriculture Network (CalCAN) and American Farmland Trust (AFT) among other agencies. Furthermore, I led an agrivoltaics research roundtable that was attended by around 40-50 agrivoltaics researchers from all over the United States, where each researcher presented to the group about their work, followed by a brainstorming session to discuss possibilities of large-scale collaborations and big ideas. The roundtable was a great success and attendees encouraged making this an annual tradition.

Furthermore, we opened a 200 KW agrivoltaics multi-technology research farm. This includes four sub-systems of 50 KW each utilizing different technologies thus allowing for simultaneously testing a wide range of combinations of different crops, agrivoltaics technologies and water stress among others.

In the summer, we had a one-acre experiment in the Campbell Tract at UCD where we tested how crops react to a wide range of light treatments, simulating different Agrivoltaics technologies. We experimented with tomatoes and peppers. Our preliminary results demonstrated that the shade positively helped the peppers and didn't impact the yields, and increased the water use efficiency of both peppers and tomatoes while reducing the yield (per acre not per water volume) of tomatoes.

In addition, my collaboration on four significant reviews on (1) soil infiltration, (2) major challenges in vadose zone, (3) arctic food and energy security, and (4) impact of photovoltaic solar energy on soil carbon came to fruition with having those review published. Other work on modeling nitrate leaching in managed aquifer recharge, performance of tomatoes under different light spectra, and modeling water infiltration under fractional wettability conditions was also submitted and published.

University of California, Davis (Helen E. Dahlke)

This research advanced the mechanistic understanding of soil water and nitrogen dynamics under Agricultural Managed Aquifer Recharge (Ag-MAR) through integrated field-informed modeling approaches. Specifically, we:

- Developed and calibrated process-based cropping system (DSSAT) models to quantify soil water storage, nitrogen transformations, nitrate leaching, and crop responses during and after winter Ag-MAR events.
- Extended the DSSAT framework to multi-year simulations to evaluate interactions between Ag-MAR and regenerative soil health practices, including compost amendments and winter cover crops.
- Developed a dual-porosity HYDRUS-1D reactive nitrogen transport model to simulate nitrate transport and transformation under large water application events, explicitly accounting for preferential flow and mobile–immobile domain exchange.
- Quantified how Ag-MAR design parameters (timing, duration, intermittency) control recharge efficiency, nitrate leaching, effective mineralization, and soil organic carbon (SOC) dynamics.
- Identified management strategies that allow groundwater recharge to be increased without increasing nitrate contamination risks, while sustaining soil health and crop productivity.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

DRI:

- A model to describe the relationship between sorptivity, effective contact angle and initial water content.
- A method to adjust soil sorptivity for different levels of soil burn severity.
- Prototype of a UAS-based robot that can carry out water drop penetration time (WDPT) tests semi-autonomously.

UNLV/DRI Collaboration:

- A method to estimate heterogeneous soil evaporation fluxes by combining lysimeter evaporation fluxes with remotely sensed surface temperature information.

UNLV:

- A machine learning surrogate model to efficiently simulate 3D unsaturated flow using Richards' equation and the van Genuchten-Mualem formulation of unsaturated hydraulic conductivity.
- Estimates of recharge efficiency at prospective managed aquifer recharge sites, which will help optimize recharge and mitigate groundwater loss and land subsidence.
- Increased adoption of geophysical survey technologies for improved groundwater monitoring and management

Washington State University (Markus Flury and Joan Wu)

- Developed methods to quantify how nanoplastics are taken up by plant roots
- Showed that under currently found plastic concentrations in soils, no negative impacts on soil physical properties will be expected
- Showed that biosolids applications have no effect whether a soil can be compacted by heavy machinery
- Showed that biodegradable plastic mulch films contribute to soil organic carbon and microbial biomass
- Adapted methods for optimal placement of Green Stormwater Infrastructure (GSI; specifically, rain gardens) in urban stormwater management

Oregon State University (Salini Sasidharan)

Practical framework for drywell implementation:
- We developed a practitioner-ready technical framework that supports the design, installation, and operation of drywells for stormwater management and groundwater recharge. The framework applies state-of-the-art monitoring and design approaches to help practitioners increase recharge efficiency, improve water quality, and reduce clogging risks, leading to more reliable and cost-effective systems.

Evidence-based guidance on subsurface data needs:
- We quantified how subsurface soil texture data resolution directly affects predicted drywell performance. This provides practitioners with clear justification for investing in the most sensitive and impactful data types, enabling better system design, reduced uncertainty in performance estimates, and more efficient allocation of project resources.

Harvesting from agrivoltaics:
- We developed a solar panel rainwater capture system that creates synergy between renewable energy generation and groundwater recharge. The system captures rainfall from panel surfaces and directs it toward infiltration, offering a dual benefit of clean

energy production and local aquifer replenishment, particularly in areas affected by irrigation-driven depletion.

Evidence-Based Identification of Major Non-Point Nitrate Sources to Inform Regulation and Management:

- Developed a model for areas with multiple land uses and high nitrate concentrations, using high-resolution mass spectrometry (HRMS) chemical fingerprinting data, with improved accuracy when coupled with microbial and isotopic data. This model can be used by scientists, engineers, and other researchers to determine which land use practices most impact high nitrate concentrations, and thus has longer-term impacts on policies regulating highest-contributing causes of non-point source pollution.

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

- Published two Manuscripts referencing the W5188 project.
- In-depth analysis of SOLUS mapping vs SoilGridsPlus mapping, particularly focusing on the informativity of oven-dry versus 33 kPa bulk density.
- Downloaded and partially analyzed OpenLandMap global gridded data (120 meter and 30 meter resolution)
- Improved speed of hydraulic property mapping (billions of grid cells) by 50%
- Hired two more MS students. Three MS students are now completing their MS projects on And NRCS-funded hydraulic property mapping project.
- Presented one invited on-campus talk with regard to the role of AI in the current project
- Presented invited talk at one international conference regarding hydraulic mapping of soil hydraulic properties (Rio de Janeiro, Federal University)
- Integrated recent research findings in ENVS 470/570 “Soil Physics” course.
- Demonstrated that more than 50% of soils exhibit bimodality on their water retention characteristics
- Made crucial contributions to an international collaboration with regard to a novel assessment of long-term sustainability of groundwater extraction in a region that provides agricultural products for 300 million people.

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

- Improved TDR-based soil sensing in support of better irrigation efficiency, water conservation, agricultural productivity, and environmental monitoring, contributing to more sustainable and resilient land and water resource management.

University of Nebraska (Aaron Daigh)

1) Space Agriculture Systems Review. The comprehensive review identified that a four-person Mars crew would require over 24,000 pounds of food, establishing the critical need for in-space crop production. The synthesis of challenges across radiation, gravity, substrate, and atmospheric domains provides researchers and space agencies with a unified framework for prioritizing technology development. This work directly supports NASA prototype systems targeting various mission deployments and informs the emerging Consortium of Space, Policy, Agriculture, Climate and Extreme Environment (SPACE2) research agenda.

2) Soil Water Sensor Comparison for Irrigation Management. Evaluation of four commercial sensors across three North Dakota field sites at four depth increments (0–122 cm) revealed significant accuracy differences among technologies. The field-calibrated Acclima TDR-310H established as a reliable reference standard provides NRCS technical staff and farmers with validated guidance for sensor selection. These findings enable more precise irrigation scheduling decisions, supporting water conservation in regions with agricultural irrigation.

3) Soil Management Legacy and Salinization Resiliency. Case study analysis demonstrated that historical soil management practices create measurable legacy effects that enhance resiliency against salinization pressures. Specific soil process indicators were identified that predict protective capacity, enabling land managers to assess vulnerability and prioritize intervention strategies. This research provides soil-processes-based insights for evaluating salt accumulation risk in production systems facing climate-induced salinization threats.

4) Cropland vs. Reference Site Soil Health Comparison. Comparison of soil health indicators across four paired sites in Nebraska MLRAs 106 and 67A revealed that no-till and manured croplands retained 72% of reference site organic matter levels, while conventional tillage sites retained only 46–69%. Phosphomonoesterase activity in all croplands was lower than reference sites, indicating dependence on external P inputs for crop production. These benchmarks establish site-specific soil health targets that account for regional edaphic and climatic variation.

5) Soil Health Systems and Hydraulic Functions. On-farm soil health systems maintained greater aggregate stability and improved pore networks after intense rainfall compared to conventional systems. Combining multiple soil health practices (cover crops, no-till, diverse rotations) increased soil carbon pools relative to single-practice small plots, demonstrating synergistic benefits. These findings validate that field-scale integrated management outperforms individual practices in building climate-resilient hydraulic functions.

6) Vadose Zone Research Priorities. The multi-institutional review (30+ contributors) identified critical knowledge gaps across spatial scales spanning 10^{-4} to 106 meters and temporal scales from seconds to decades. Six priority research areas were defined: scaling/modeling, soil

moisture monitoring, surface energy balance, preferential flow-biogeochemistry interactions, fire-hydrology interactions, and emerging contaminants including microplastics and PFAS. This synthesis provides funding agencies and researchers with a coordinated roadmap for vadose zone science advancement.

7) Mycorrhizal Fungi for Zinc Biofortification. AMF inoculation mitigated Zn toxicity at high fertilization rates (64–96 mg Zn dm^{-3}) where non-inoculated lettuce showed yield decline. Inoculated plants demonstrated superior growth and Zn absorption, enabling effective biofortification without sacrificing production. This research establishes a practical biological tool for enhancing vegetable nutritional value to address global Zn deficiency affecting millions of people.

8) Large-Scale Slope Failures in North Dakota. Of 66,894 mapped landslides, 2,014 large-scale failures (>100,000 m^2) were identified, occurring predominantly on gentler slopes (mean 7.9°) within Sentinel Butte (51%), Bullion Creek (13%), and Oahe Formations (9.6%). Statistical analysis ($p < 0.001$) identified that sodium adsorption ratio and total dissolved solids correlate with slope instability. These findings provide geotechnical engineers and planners with formation-specific risk factors for infrastructure siting decisions.

9) Value of Agricultural Scientific Meetings. Analysis of ASA-CSSA-SSSA Annual Meetings (2014–2023) estimated $64.2 billion in socioeconomic value from presented research content. The study documented both quantifiable impacts (knowledge dissemination, collaboration initiation) and unquantifiable benefits (career transformation, community building) that scientific meetings provide. This valuation supports continued investment in scientific conference infrastructure as essential for agricultural research advancement.

10) Nitrous Oxide Emissions from Irrigated Sugar Beet. Cumulative N_2O emissions increased linearly with N fertilization rates across both study years, with 2023 emissions at least 50% greater than 2022 due to higher soil moisture. Fertilizer-induced emission factors averaged 1.02% (0.71% in 2022, 1.32% in 2023), closely matching the IPCC default of 1%. This validation confirms that default emission factors can reasonably estimate N_2O from understudied irrigated crops, improving greenhouse gas inventory accuracy for sugar beet production.

11) TDR Sensor Field Calibration. Field-specific calibration equations were developed for a time-domain reflectometry sensor with extension pipe, improving accuracy for vertical installation in soils with low coarse fragment content. The calibrated sensor served as a validated reference standard for subsequent multi-sensor comparison studies. This technical advancement supports adoption of sensor-based irrigation scheduling for improved water use efficiency in Northern Great Plains agriculture.

Oklahoma State University (Tyson Ochnser)

- We evaluated the correlations between soil moisture predictions from the SOILWAT2 model and NASA's SPORT LIS model against measurements from >1,000 in situ monitoring stations across the US. Averaged across all stations, both models showed nearly identical correlations coefficients, and the root mean squared error was slightly lower for SOILWAT2.
- Soil moisture maps were generated from cosmic-ray neutron rover surveys in four watersheds within Oklahoma: the Little Washita River Watershed, the Fort Cobb Watershed, the Wild Horse Creek Watershed, and the Deep Red Creek Watershed. Cosmic-ray neutron rover surveys were completed on two dates in each watershed to capture soil moisture patterns in relatively wet and dry conditions.
- We improved the soil hydraulic property estimates that were needed to estimate drainage rates across Oklahoma using in situ soil moisture observations. We showed that Rosetta3 produces saturated hydraulic conductivity estimates that result in unrealistically high drainage estimates. However, we developed a method for using Rosetta3 soil water retention parameters to estimate hydraulic conductivity using the "C2" model within Rosetta1, leading to improved drainage estimates.
- We collaborated with colleagues in other states to maintain coordinated in situ soil moisture sensor testbeds. Soil moisture sensor testbeds in Kansas, Oklahoma, Texas, and Maryland are being used to test soil moisture sensing technologies in different soils and climates. Manuscripts describing results from the Oklahoma and Texas testbeds were submitted to a special issue of Vadose Zone Journal.
- We released an improved version (v. 10) of the open-access soil physics textbook "Rain or Shine: An Introduction to Soil Physical Properties and Processes". The most significant improvement in version 10 is the addition of video summaries of each chapter that were generated using the AI tools in Google NotebookLM.

University of Kentucky (Ole Wendroth)

- We have continued a field experiment in a farmer's field in West Kentucky that has the goal to simulate soil hydrological processes and crop growth. Typically, field soils developed on Karst topography reveal elevation differences and a substantial spatial variability of soil properties and crop yield at the hectare scale. The aim of the computer simulations is to support farmers' decisions on variable rate nitrogen application and irrigation for reducing the environmental footprint of agricultural production and improve environmental and food quality.
- In the same project, we investigate the monitoring of the land surface and crop growth status with UAVs. First investigations show that high-resolution measurements of

Normalized Difference Vegetation Index correlate with the spatial crop yield pattern in a farmer's field.
- In another graduate students' project, we are investigating opportunities for quantifying mineral soil nitrogen concentration via spectroscopy.

North Carolina State University (Josh Heitman)

- We determined the effects of biocrusts on soil hydrology and energy balance.
- We developed methods to estimate soil thermal properties from other more accessible soil property information.
- We developed methods to calculate soil hydraulic properties after deformation.
- We determined management strategies to improve the hydrothermal environment for spring crops.

North Dakota State University (Kang Liang)

- Quantified effects of land use and management practices (tillage, tile drainage, cover crop, energy crops) on streamflow, nitrate loading, and water quality across multiple watersheds.
- Demonstrated strong bias in nitrate load estimates when using regression methods with sparse data.
- Identified the tradeoffs between soil health benefits and downstream water quality and ecosystem health under no-till and conservation tillage.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

- We (in collaboration with Josh Heitman at NCSU) used neural networks to estimate soil thermal conductivity as a function of water content.
- We developed a model to estimate soil electrical conductivity as a function of water content.
- We developed a model to describe winter rye cover crop growth.
- We (in collaboration with Josh Heitman at NCSU) described the use of thermo-TDR sensors to measure dynamic soil temperature, water content, bulk density, water flow rates, and soil water evaporation rates.
- We developed a method to estimate soil water content distribution along a TDR waveguide.
- We used machine learning models to estimate soil erosion susceptibility.
- We developed and implemented AI-based Smart Rhizoboxes to enable real-time tracking of root growth in response to soil compaction and water films

- We demonstrated the impact of compaction on soil water distribution and seedling growth.
- We developed a TDR method to estimate soil bacterial cell counts.
- We developed a method to field calibrate soil heat flux plates.
- We (in collaboration with Josh Heitman at NCSU) developed a method to reduce wall flow in soil samples collected in plastic liners.
- We utilized the Daily Erosion Project to refine the relationship between crop residue cover and hillslope soil erosion estimates

Virginia Tech (Ryan Stewart)

- Developed recommendations for nursery producers to amend pine bark growing media, which can help to reduce fertilizer and irrigation costs.
- Provided training on best-management practices for utility-scale solar developers, which will help to improve environmental quality in solar sites.
- Implemented strategies to reduce nutrient losses from urban bioretention systems, which will help to improve stormwater quality.

University of Delaware (Yan Jin)

- Maintaining a field site for long-term monitoring of chemical/physical properties and related biogeochemical processes to assess how saltwater intrusion may affect coastal soil functions.
- Improved interpretation of porewater mixing by incorporating stable water isotopes into end member mixing models, compared with salinity-only approaches.
- Developed and validated an Evaporative Enrichment Index (EEI) that quantitatively distinguishes
- conservative freshwater–seawater mixing from non-conservative isotopic modification due to
- evaporation.
- Demonstrated that stable water isotopes combined with EEI provide greater sensitivity to
- subsurface hydrologic processes than electrical conductivity alone across tidal regimes.
- Generated a transferable analytical framework that can be adopted by other coastal and wetland
- researchers investigating saltwater intrusion and marsh hydrology.
- Developed a procedure to investigate the impact of wetting-drying cycles and salinity on soil hydraulic properties.

- Developed laboratory methodology to assess how soil hydraulic properties change in response to salinity and persist after salt dilution/removal, with and without an organic amendment.
- Demonstrated the effectiveness of organic amendments to mitigate the impacts of salinity on soil saturated hydraulic conductivity.
- Developed a laboratory column setup to simulate capillary fringe fluctuations due to sea-level change and coastal flooding and quantify their impacts on soil carbon emissions, integrating Eh, EC, and temperature sensors for continuous, real-time monitoring of soil redox dynamics and carbon fluxes.
- Established collaboration with the U.S. Army Engineer Research & Development Center (ERDC) researchers to investigate global distribution patterns of soil organic matter quality, leveraging existing soil samples collected across the United States and their associated physicochemical property datasets.
- Demonstrated subsoils as a significant organic carbon reservoir across a forest–wetland transition and that they retain measurable microbial activity and carbon utilization potential.

University of Wisconsin-Madison (Jingyi Huang)

- Published machine learning-based high-resolution soil moisture model (ML-HRSM 2.0) for the continental US
- Developed printed soil moisture and nitrate sensors for nutrient transport modeling

Michigan State University (Jiquan Chen)

- Participated in synthesizing ecosystem responses to environmental change and management at regional and global scales.

Michigan State University (Wei Zhang)

- Developed machine learning models capable predicting plant uptake of PFAS
- Developed molecular dynamics simulations for interactions of prion fibrils with aromatic carbon surfaces
- Demonstrated metallomes of carrot and wheat are primarily controlled by plant growth stages
- Showed potential to optimize crop metallomes with agricultural practices for enhanced nutrition and food safety.

University of Florida (Ebrahim Babaeian)

- Developed an integrated remote sensing framework that uses L-band passive observations, physically-based tau-omega radiative transfer model and machine learning to estimate and map field-scale surface-to-root zone soil moisture in sandy agricultural soils.
- Continued and maintained long-term in situ measurements of soil profile moisture content and matric potential using multiple types of sensors, and soil hydraulic properties to support irrigation management for Florida's sandy agroecosystems.
- Supervised 10 graduate students (MS and PhD), serving as a major advisor for four students and committee member for six students.
- Contributed to the University-wide Faculty artificial intelligence (AI) Working Group, supporting interdisciplinary coordination and strategic integration of AI across research and teaching initiatives.

Connecticut Agricultural Experiment Station (Yingxue Yu)

- Biodegradable and conventional nanoplastics are mobile in soils
- Soil solution promotes the aggregation of nanoplastics through eco-corona formation and hetero-aggregation
- Soil solution does not affect the transport of nanoplastics under low ionic strength, but hinder the transport under high ionic strength due to promoted aggregation
- Biodegradable plastic mulch will be a sustainable alternative to conventional plastic mulch if proper disposal is met

Texas A&M University (Briana Wyatt)

- Developed estimates of groundwater recharge for the Carrizo-Wilcox aquifer.
- Quantified impacts of woody plant encroachment on groundwater resources in the Post Oak Savannah ecoregion.
- Advised local government officials regarding potential impacts of industrial water use on Carrizo-Wilcox aquifer.

Texas A&M University (Binayak P. Mohanty)

- Our observational (ground-based network, UAV and satellite remote sensing) studies along with advanced process-based, statistical, and data-driven models made significant impact in better understanding of the environmental physics, soil hydrology, and biogeochemistry. We have developed a new optimal mass transport theory to describe coupling soil moisture and evapotranspiration at remote sensing footprint scale. This provides new insight into how different hydroclimates optimally regulate effective rooting depth in various ecosystems. In another study, we have adapted graph neural network and other data-driven models (e.g., Random Forest) for describing various natural and anthropogenic factors influencing the fate and transport of heavy metals and organic contaminants in the root zone in various urban gardens across Texas. Further, we studied deep vadose zone redox processes in upland and low land soils, as well as root zone biogeochemical processes under different land use, landcovers, hydrologic setup, and agricultural management practices. Findings from these studies will help prescribe new tools and techniques for site assessment, management adaptation, and contamination mitigation strategies in row crop agriculture, urban agriculture, grassland, prairie, and forest ecosystems.

- Scientists, engineers, and stakeholders are using our findings for better understanding of water, energy, carbon, and other elemental transport processes and designed efficient irrigation, tillage, soil amendment/remediation, and cropping practices. They also used the scientific information to model how surface water and ground water, stream and aquifer, blue and green water, terrestrial and oceanic water interact at interfaces resulting in biogeochemical processes and redox states, leading to improved inland and coastal zone management. Our scientific findings and techniques provided advanced global application tools for soil and water management, crop production, climate forecasts, flood and drought prediction, groundwater recharge estimation, GHG emission, and pollution control.
- Our research enhanced the public awareness of sustainable soil, water, and environmental management for agricultural practices, urban gardens, coastal margin restoration, and soil and water quality.

University of Hawaiʻi at Mānoa (Jing Yan)

- Initiated studies to integrate and interpret legacy datasets on soil physical and hydraulic properties across tropical Hawaiian landscapes, aiming to develop improved frameworks for sampling design, soil characterization, and predictive modeling of hydraulic behavior in tropical soils. This curated dataset supports more informed soil-water management decisions in both agricultural and natural ecosystems.
- Developed mechanistic studies on how soil microbes, including soil bacteria and fungi, generate feedback that alter soil physical and hydraulic processes; to understand how microbial activity evolves under different environmental conditions (e.g., drying) and how these shifts drive changes in beneficial soil functional properties such as water retention and flow.

University of Tennessee-Knoxville (Xi Zhang)

- Bridging micro- and field-scale processes to advance knowledge of the interactions between soil physical and biogeochemical processes under different management practices that contribute to soil and agroecosystem services.
- Integrating column and field experiments to untangle the underlying mechanisms via which contaminants shape transport pathways for predicting their possible migration to groundwater through the soil.

Montana State University (Jack Brookshire)

- We contributed to a published review paper on research frontiers in vadose zone processes.
- We published a paper on process-based and observation-constrained analysis of carbon cycling in U.S. rangelands.

Outputs

University of California, Riverside (Hoori Ajami)

Research findings were disseminated via:

- 13 publications in peer-reviewed journals
- 22 conference abstracts and presentations
- Taught 2 upper division undergraduate courses in Spatial Analysis and Remote Sensing (4 units), and Water Resources (4 units).
- Served on 1 PhD dissertation committee
- Served as an Associate Editor of California Agriculture and Journal of Hydrology
- Served as the Editor of Journal of Hydrology-X and Hydrological Processes

University of California, Riverside (Jirka Šimůnek)

Research findings were disseminated via:

- 22 publications in peer-reviewed journals
- 12 conference abstracts
- Taught 4 short courses on HYDRUS modeling
- Delivered 6 invited and keynote presentations
- Attended 5 scientific meetings and conferences

University of California, Davis (Thomas Harter)

Research findings were disseminated via:

- 6 publications in peer-reviewed journals
- Numerous outreach, extension, and stakeholder engagement activities (~90 events)
- Delivered invited trainings and workshops for policy makers, judges, and water managers

University of California, Davis (Majdi Abou Najm)

Research findings were disseminated via:

- 7 publications in peer-reviewed journals
- 7 conference abstracts and presentations
- Delivered 3 webinars
- Organized California's third Agrivoltaics Conference
- Led a national agrivoltaics research roundtable

University of California, Davis (Helen E. Dahlke)

Research findings were disseminated via:

- 1 publication in a peer-reviewed journal
- 2 peer-reviewed manuscripts submitted/in review
- 6 conference abstracts and presentations
- Completed 1 PhD dissertation

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

Research findings were disseminated via:

- 5 publications in peer-reviewed journals
- 18 conference abstracts and presentations

Washington State University (Markus Flury and Joan Wu)

Research findings were disseminated via:

- 11 publications in peer-reviewed journals
- 7 conference abstracts and presentations
- Delivered 3 webinars

Oregon State University (Salini Sasidharan)

Research findings were disseminated via:

- 2 publications in peer-reviewed journals

- 9 conference abstracts and presentations
- Multiple invited workshops, field demonstrations, and stakeholder engagement activities

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

Research findings were disseminated via:
- 2 publications in peer-reviewed journals
- 2 conference abstracts and presentations
- Integration of research findings into undergraduate and graduate teaching

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

Research findings were disseminated via:
- • 11 publications in peer-reviewed journals
- • 2 research reports
- • 25 conference abstracts and presentations

University of Nebraska (Aaron Daigh)

Research findings were disseminated via:
- • 11 publications in peer-reviewed journals
- • 7 conference abstracts

Oklahoma State University (Tyson Ochnser)

Research findings were disseminated via:
- • 3 publications in peer-reviewed journals
- • Numerous conference abstracts, presentations, and invited seminars
- • Released Version 10 of the open-access soil physics textbook Rain or Shine
- • Ongoing mentoring of 5 PhD students

University of Kentucky (Ole Wendroth)

Research findings were disseminated via:
- 1 publication in a peer-reviewed journal
- 2 conference abstracts and presentations
- 3 international invited presentations

North Carolina State University (Josh Heitman)

Research findings were disseminated via:
- 15 publications in peer-reviewed journals
- 20 conference abstracts and presentations
- 1 research report
- 1 trade article

North Dakota State University (Kang Liang)

Research findings were disseminated via:
- 5 publications in peer-reviewed journals
- 3 conference abstracts and presentations

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

Research findings were disseminated via:
- 13 publications in peer-reviewed journals
- 9 conference abstracts and presentations
- 2 research reports

Virginia Tech (Ryan Stewart)

Research findings were disseminated via:
- 3 publications in peer-reviewed journals
- 1 peer-reviewed conference proceedings paper
- 6 conference abstracts and presentations
- 2 research reports

University of Delaware (Yan Jin)

Research findings were disseminated via:
- Peer-reviewed journal publications
- 2 conference abstracts and presentations
- 1 research report
- Session proposal accepted for EGU

University of Wisconsin-Madison (Jingyi Huang)

Research findings were disseminated via:

- 9 publications in peer-reviewed journals
- 13 conference abstracts and presentations
- Extensive manuscript review and graduate mentoring activities

Michigan State University (Jiquan Chen)

Research findings were disseminated via:
- 3 publications in peer-reviewed journals
- 2 conference abstracts and presentations

Michigan State University (Wei Zhang)

Research findings were disseminated via:
- 1 publication in a peer-reviewed journal
- 8 conference presentations

University of Florida (Ebrahim Babaeian)

Research findings were disseminated via:
- 4 publications in peer-reviewed journals
- 11 conference abstracts and presentations

Connecticut Agricultural Experiment Station (Yingxue Yu)

Research findings were disseminated via:
- 2 publications in peer-reviewed journals
- 3 conference abstracts and presentations

Texas A&M University (Briana Wyatt)

Research findings were disseminated via:
- 3 publications in peer-reviewed journals
- 2 research reports
- 3 conference abstracts and presentations

Texas A&M University (Binayak P. Mohanty)

- The coupling between soil moisture (SM), evapotranspiration (ET), and Gross Primary Productivity (GPP) governs key dynamics of Earth's climate, available water resources, and biosphere productivity. Yet, prevailing conceptual and mechanistic models fall short of capturing the physics of water–energy exchange across diverse hydroclimates. We introduced an optimal transport framework based on the hypothesis that hydroclimates regulate SM-ET coupling near a quasi-optimum state. This state is characterized by least action principle, defined by dynamic convolution between the water potential gradient (Δω) driving land-to-atmosphere moisture flux and the time weighted mass flux (referred as the SM-ET coupling metric, λ_(SM-ET)). Global validation of this framework using decadal (2010–2019) SM and ET remote sensing data reveals widespread convergence toward the least action state across hydroclimatic zones, supporting the notion of emergent climatic regulation in SM–ET coupling. Overall, this framework provides a physically grounded way to study water–energy interactions across diverse environments.

- Climate variability increasingly threaten global crop productivity. We formulated a multi-objective optimization problem for climate-smart irrigation and developed a dual-index framework for assessing irrigation practices across productivity and climate impact dimensions.

- Regenerative agriculture is pivotal for mitigating climate change, with no-tillage practices on cropland being generally effective at raising soil carbon (SOC). However, the compound impact of soil and environmental factors on SOC gain after transitioning to no-till systems are being under investigation in the current times. Synthesizing various local and regional data sources, and using imbalanced machine learning classification schemes, we quantified key thresholds for classifying SOC gain potential by switching from conventional tillage to long-term no-tillage with residue retention. These findings will be utilized in various decision Support Systems.

Research findings were disseminated via refereed journal publications, conference proceedings, project reports, and a number of presentations at national and international meetings (see the publication section below).

- 7 publications in peer-reviewed journals
- 4 book chapters
- 3 project reports
- 8 technical abstracts
- 12 presentations at national and international meetings

University of Hawaiʻi at Mānoa (Jing Yan)

Research findings were disseminated via:

- 1 publication in a peer-reviewed journal
- 5 conference abstracts
- 7 presentations

University of Tennessee-Knoxville (Xi Zhang)

Research findings were disseminated via:

- 12 publications in peer-reviewed journals
- 7 conference abstracts and presentations

Montana State University (Jack Brookshire)

Research findings were disseminated via:

- 2 publications in peer-reviewed journals

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

Research findings were disseminated via:

- 13 publications in peer-reviewed journals
- 3 conference abstracts and presentations

Activities

University of California, Riverside (Hoori Ajami)

- Characterizing mountain system recharge to determine the degree of connectivity between the mountain and valley aquifers
- Quantifying mountain aquifer recharge in 164 catchments in the Western US
- Contributing to partitioning of soil moisture sensor data to matrix and macropore domain
- Contributed to developing computationally efficient hydrologic models by externally coupling overland flow, vadose zone and groundwater flow models

University of California, Riverside (Jirka Šimůnek)

In 2025, we organized four short courses on the use of HYDRUS models. The first three courses were on-site (in Prague, mainly for participants from Europe; in Yantai, China; and in Sede Boqer, Israel), while the fourth was online and mainly for participants from North America (the US and Canada). Over 150 students participated in these short courses.

Meetings attended:

1. W4188 Western Regional Soil Physics Group Meeting, Las Vegas, Nevada, January 1-3, 2025.
2. International Conference in honor of "Rien" van Genuchten, on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.
3. International Workshop on Soil-Hydrology-Ecosystem, School of Hydraulic and Civil Engineering, Ludong University, Yantai, China, August 2–5, 2025.
4. Annual Meeting of the Soil Science Society of America, Salt Lake City, Utah, November 9-12, 2025.
5. Fall Meeting of American Geophysical Union, New Orleans, Louisiana, December 15-19, 2025.

HYDRUS Teaching:

1. Teaching a short course "Advanced modeling of water flow and contaminant transport in porous media using the HYDRUS software packages" organized by the Czech University of Life Sciences, Prague, Faculty of Agrobiology, Food and Natural Resources, Prague, Czech Republic, June 23-25, 2025. Other instructors: M. Th. van Genuchten and R. Kodešová (30 participants, mostly from Europe).
2. Teaching a short course "Advanced modeling of water flow and contaminant transport in porous media using the HYDRUS software packages" before the International Workshop on Soil-Hydrology-Ecosystem, School of Hydraulic and Civil Engineering, Ludong University, Yantai, China, July 31-August 2, 2025. Sole instructor (49 participants).

3. Teaching an online short course "Advanced modeling of water flow and contaminant transport in porous media using the HYDRUS software packages," organized by PC Progress, Prague, Czech Republic, September 2–3, 2025. Sole instructor (49 participants, mostly from the US and Canada).
4. Teaching a short course “Advanced modeling of water flow and contaminant transport in porous media using the HYDRUS software packages,” at the Sede Boker Campus of Ben Gurion University, Israel, September 9-11, 2025. Another instructor: N. Lazarovitch, 24 participants.

Invited Presentations:

1. Keynote presentation: “The Legacy of Rien van Genuchten, a Recipient of the 2023 Wolf Prize for Agriculture,” at the International Conference in honor of “Rien” van Genuchten, on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.
2. Keynote presentation: “HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes”, at the International Conference in honor of “Rien” van Genuchten, on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.
3. Invited presentation, “Numerical Modeling of Vadose Zone Processes using HYDRUS and its Specialized Modules,” Qinghai Institute of Salt Lake, Xining, China, July 27, 2025.
4. Invited presentation, “Numerical Modeling of Vadose Zone Processes using HYDRUS and its Specialized Modules,” State Key Laboratory of Cryospheric Science and Frozen Soil Engineering, Lanzhou, China, July 28, 2025.
5. Invited presentation “HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes”, International Workshop on Soil-Hydrology-Ecosystem, School of Hydraulic and Civil Engineering, Ludong University, Yantai, China, August 3, 2025.
6. Invited presentation “HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes”, Nanjing University, Nanjing, China, August 6, 2025.

Abstracts:

- Brunetti, G., and J. Šimůnek, Bayesian inference in physically-based vadose zone Modeling: The good, the bad, and the ugly, invited presentation, Session: HS3.8 – Advances in Model Inference, Diagnostics, Sensitivity, Uncertainty Quantification and Bayesian Approaches in Environmental Systems Models, EGU25-2130, EGU Annual Meeting, Vienna, Austria, April 27-May 2, 2025.
- Šimůnek, J., The Legacy of Rien Van Genuchten, a Recipient of the 2023 Wolf Prize for Agriculture, International Conference in honor of "Rien" van Genuchten on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.

- Jacques, D., and J. Šimůnek, The HPx tool for geochemical and coupled reactive transport simulations for engineered and environmental porous systems, International Conference in honor of "Rien" van Genuchten on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.
- Šimůnek, J., M. Šejna, G. Brunetti, D. Jaques, and M. Th. van Genuchten, HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes, International Conference in honor of "Rien" van Genuchten on the occasion of his 80th birthday, Rio de Janeiro, Brazil, May 7-9, 2025.
- Rahman, A. T. M. S., J. Šimůnek, S. A. Bradford, H. Ajami, M. B. Meles, L. Chen, and A. Szymkiewicz, An externally coupled multi-model framework for integrated surface-subsurface flow and solute transport on hillslopes, California Water and Environmental Modeling Forum, Folsom, California, May 12-14, 2025.
- Tigabu, T. B., A. Casillas-Trasvina, M. Meles, S. Bradford, R. T. Bailey, and J. Šimůnek, Spatio-temporal modeling of groundwater flow dynamics under extensive irrigation in the San Joaquin Valley, California Water and Environmental Modeling Forum, Folsom, California, May 12-14, 2025.
- Simunek, J., HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes, 2025 Annual Academic Conference on "Soil Physics and Smart Agriculture', the Soil Physics Committee of the Chinese Society of Soil Science, August 2-5, 2025.
- Šimůnek, J., Advances in numerical modeling of infiltration processes across scales, Invited presentation, H12B-03. Advancing Hydrologic Processes to Improve Flood Prediction, ID#1859454, AGU Annual Meeting, New Orleans, Louisiana, December 15-19, 2025.
- Meles, M. B. A. T. M. S. Rahman, H. Ajami, S. A. Bradford, and J. Šimůnek, A Computationally Efficient Hydrological Modeling Framework: Coupling Specialized Physics-Based Flow Models at the Watershed Scale, ID#1980275, AGU Annual Meeting, New Orleans, Louisiana, December 15-19, 2025.
- Zhou, T., G. Brunetti, N. Ruud, J. Šimůnek, W. Cui, A. Liao, P. Nasta, J. Gao, E. Levintal, C. P. Garcia, and H. E Dahlke, Evaluating pesticide leaching and water transit times in deep vadose zones under agricultural managed aquifer recharge, H23A-03, ID#1893335, AGU Annual Meeting, New Orleans, Louisiana, December 15-19, 2025.
- Vahedian, F., J. A. K. Silva, J. Šimůnek, and J. E. McCray, A practical HYDRUS-based modeling framework for estimating PFAS mass discharge from the vadose zone to groundwater, Fourteenth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Abstract 51, Fort Worth, Texas, May 31-June 4, 2026.
- Renaud, J., A. Peña Echeverría, C. Contreras, J. Šimůnek, S. Leray, A. de la Fuente, and F. Suárez, Evaporation of bare soils in a high-altitude basin, Tarapacá Region – Experimental and numerical integration with field measurements, Poster presentation, 1st Congress on Salt Flats and High Andean Ecosystems, Calama, Chile, November 7, 2025.

University of California, Davis (Thomas Harter)

- Maintained highly efficient water and nutrient management practices in almond orchard of a 140- acre commercial operation, with nutrient use efficiency above 90%.
- In nearly 90 events, reached out to over 3,000 local, state, national, and international policy- and decision-makers, researchers, and grower-representatives about nonpoint source pollution of groundwater and its sources, and about sustainable groundwater management.
- Validated and improved watershed model for the upper Scott Valley watershed
- Developed a methodology for interpreting geophysical data for development of aquifer textural classification and published in high impact journal
- Provided training on groundwater hydrology to over 30 Western U.S. judges and justices
- Educated water managers, agency personnel, growers, agricultural representatives, leaders in the agricultural banking sector, and attorneys on California groundwater issues during two Water Education Foundation tours: 1-Day Groundwater Tour and 3-Day Central Valley tour.
- Workshops to educate water managers, growers, grower organizations, NGOS, local/regional/state representatives and decision/policy makers on the relationship between crop management practices and groundwater pollution based on nitrogen budgets, current and historic groundwater pollution, groundwater forensics to identify sources of nitrate (by specific crops), application of machine-learning algorithms to identify agriculture's role in groundwater nitrate pollution, and on N balance; undertstanding the dynamics of future groundwater pollution improvements from current changes in management practices.
- Over a dozen consultation meetings with regulatory agencies, agricultural coalition representatives, and environmental NGOs on the technical merits of proposed policy solutions to regulating agricultural nitrate discharges to groundwater.
- Monthly consultations with state regulatory water rights division on developing drought enforcement assessment tools
- Monthly public meetings with state regulatory water quality division to develop best science for regulatory limit setting on nitrogen use in agriculture

University of California, Davis (Majdi Abou Najm)

A lot of focus was given to outreach and building pilot experiments in agrivoltaics which made large impact in terms of bringing attention and interest in this new and promising technology. This year, I also participated in numerous talks, presentations, and outreach meetings with different stakeholders. Furthermore and in collaboration with the German-American Chamber of

Commerce, we built on our success over the past 2 years and launched California's third conference on Agrivoltaics, which was very well received and attended (attendance around 150) with representations from growers, to policy, energy and industry groups. The conference worked as a catalyst bringing all those groups together and help each group connect with other groups. Also, I have worked with policy groups including California Climate and Agriculture Network (CalCAN) and American Farmland Trust (AFT) among other agencies. Furthermore, I led an agrivoltaics research roundtable that was attended by around 40-50 agrivoltaics researchers from all over the United States, where each researcher presented to the group about their work, followed by a brainstorming session to discuss possibilities of large-scale collaborations and big ideas. The roundtable was a great success and attendees encouraged making this an annual tradition.

Furthermore, we opened a 200 KW agrivoltaics multi-technology research farm. This includes four sub-systems of 50 KW each utilizing different technologies thus allowing for simultaneously testing a wide range of combinations of different crops, agrivoltaics technologies and water stress among others.

In the summer, we had a one-acre experiment in the Campbell Tract at UCD where we tested how crops react to a wide range of light treatments, simulating different Agrivoltaics technologies. We experimented with tomatoes and peppers. Our preliminary results demonstrated that the shade positively helped the peppers and didn't impact the yields, and increased the water use efficiency of both peppers and tomatoes while reducing the yield (per acre not per water volume) of tomatoes.

In addition, my collaboration on four significant reviews on (1) soil infiltration, (2) major challenges in vadose zone, (3) arctic food and energy security, and (4) impact of photovoltaic solar energy on soil carbon came to fruition with having those review published. Other work on modeling nitrate leaching in managed aquifer recharge, performance of tomatoes under different light spectra, and modeling water infiltration under fractional wettability conditions was also submitted and published.

University of California, Davis (Helen E. Dahlke)

- Developed and calibrated process-based DSSAT cropping system models using field data from winter Agricultural Managed Aquifer Recharge (Ag-MAR) experiments to simulate soil water dynamics, nitrogen transformations, nitrate leaching, and crop response.
- Designed and evaluated Ag-MAR management scenarios varying recharge timing, duration, and intermittency to quantify impacts on groundwater recharge efficiency, soil water storage, nitrate leaching, and effective mineralization.

- Extended simulations to multi-year modeling frameworks to assess long-term interactions between repeated Ag-MAR implementation and regenerative soil health practices, including compost amendments and winter cover crops.
- Developed, parameterized, and calibrated a dual-porosity HYDRUS-1D reactive nitrogen transport model explicitly representing preferential flow, mobile–immobile domain exchange, and nitrogen transformation processes.
- Conducted global sensitivity and uncertainty analyses to identify dominant transport and reaction controls on nitrate fate across soil profiles with contrasting textures and legacy nitrate storage.
- Integrated root-zone scale (DSSAT) and profile-scale (HYDRUS-1D) modeling approaches to bridge soil physical, biogeochemical, and management perspectives on Ag-MAR impacts.
- Quantified the effects of Ag-MAR design parameters on recharge efficiency, nitrate leaching risk, soil organic carbon dynamics, and growing-season water and nitrogen availability.
- Completed and successfully defended a PhD dissertation advancing mechanistic understanding of soil water and nitrogen dynamics under managed recharge systems.

Abstracts

- Dahlke, H. E. (2025). Fate and transport of contaminants under agricultural managed aquifer recharge. Presentation at the W5188 Soil Physics Multistate Annual Meeting, Las Vegas, NV, January 2, 2025.
- Dahlke, H. E. (2025). Agricultural Managed Aquifer Recharge (Ag-MAR): A method for sustainable groundwater management. Invited presentation at the WaterMARK Workshop, Belfast, Northern Ireland, April 8–11, 2025.
- Dahlke, H. E. (2025). Agricultural Managed Aquifer Recharge (Ag-MAR): A method for sustainable groundwater management. Invited seminar at the Helmholtz Centre for Environmental Research (UFZ), Leipzig, Germany, April 15, 2025.
- Cui, W., Dahlke, H. E., Zhou, T., & Kisekka, I. (2024). Modeling soil water dynamics and nitrogen cycling under agricultural managed aquifer recharge (Ag-MAR). ASA-CSSA-SSSA International Annual Meeting, San Antonio, TX.
- Cui, W., Dahlke, H. E., Zhou, T., & Kisekka, I. (2024). Influence of agricultural managed aquifer recharge (Ag-MAR) and organic amendments on soil nitrogen balance. 79th Soil and Water Conservation Society International Annual Conference, Myrtle Beach, SC, July 21–24, 2024.
- Dahlke, H. E., Zhou, T., Bonarrigo, A., Levintal, E., & Prieto Garcia, C. (2025). Agricultural Managed Aquifer Recharge (Ag-MAR): A Method for Sustainable Groundwater Management. GSA Connects 2025, San Antonio, Texas, USA.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

DRI:

1. Evaluated a model to describe the relationship between sorptivity, effective contact angle and initial water content.
2. Helped develop a UAS-based robot that can carry out water drop penetration time (WDPT) tests semi-autonomously
3. Evaluated methods to measure sorptivity of sub-critically water-repellent soil in the field
4. Worked on an improved understanding of water infiltration into initially dry soils
5. Shed light on the chemical nature of fire-induced soil water repellency.

UNLV/DRI Collaboration:

1. Extended the research infrastructure at the Scaling Environmental Processes in Heterogeneous Arid Soils (SEPHAS) facility by a thermal camera.
2. Evaluated the evaporation differences between bare soil and biocrust-covered soil.
3. Developed a method to grow biocrust for laboratory evaporation experiments.

UNLV:

- Developed a data assimilation workflow for incorporating borehole nuclear magnetic resonance surveys into simulations of groundwater flow through the deep unsaturated zone.
- Improved understanding of the ways in which distinct types of floods flush solutes from floodplain soils.
- Identified optimal algorithms and training criteria for simulating 3D unsaturated flow using machine learning surrogates.
- Evaluated the impact of tension-driven unsaturated flow on long-term recharge efficiency during flood managed aquifer recharge.
- Developed a simplified hillslope-scale hydrological model.

Washington State University (Markus Flury and Joan Wu)

- Investigated long-term interactions between biosolids application and soil compaction using a 26-year field experiment to quantify impacts on soil physical and hydraulic properties.
- Quantified the effects of microplastic type, size, and concentration on soil compression behavior, void ratio dynamics, and soil resilience to compaction.
- Demonstrated that biodegradable plastic mulch films contribute to soil organic carbon and microbial biomass pools.
- Developed and refined analytical methods to quantify micro- and nanoplastics in rainwater and soil samples.
- Developed isotope-based techniques to trace polymer-derived carbon fluxes from biodegradable plastics into soil organic matter, carbon dioxide, and microbial biomass.

- Conducted controlled experiments to quantify plant uptake of micro- and nanoplastics across different growth media (hydroponics, agar, and soil).
- Demonstrated size-dependent nanoplastic uptake mechanisms and associated plant stress responses.
- Adapted and validated a hydrologic Sensitivity Index approach for optimal placement of Green Stormwater Infrastructure (rain gardens) using publicly accessible geospatial datasets.
- Corroborated indexing approaches through process-based hydrologic assessment and field validation.

Oregon State University (Salini Sasidharan)

North Willamette Research and Extension Center, Oregon, USA

- Monthly samples for chemical fingerprinting, nutrients (NO3, NO2, NH3, TKN, PO4), nitrate and water isotopes, bioinformatics, trace metals, e. coli
- Monthly tracking of water quality parameters: temperature, pH, DO, ORP, EC, nitrate, turbidity, alkalinity
- Monthly check of vadose zone Lysimeters for any collected water
- Processing samples in lab for further analysis (SPE, total DNA isolation)
- Data collection and processing of the DeepVadoSense facility.
- Monthly Geophysical Electrical resistivity tomography.
- Transient Electrical Magnetic survey.
- Field-scale recharge-controlled experiment during summer 2025.
- Dimensioning and installation of rain gutters in an array of solar panels.
- Sampling and analysis of contaminant leaching from solar panels.
- Modeling of water quantity using Hydrus 2D axisymmetric simulations.

Hermiston, Oregon, USA

- Hydrogeological data collected and processed to delineate the thickness and extent of the vadose zone, as well as to identify confining layers and the unconfined aquifer in Lower Umatilla basin.
- Design specifications for drywell, monitoring and vadose zone wells completed, including the total depths and the number and type of sensors to be deployed and the installation depth for each sensor at the Lower Umatilla basin.
- Conducted geophysical surveys using towed-Transient. Electromagnetic Method (tTEM) and walk-Transient Electromagnetic Method (WalkTEM) methods were conducted to characterize subsurface conditions Lower Umatilla basin.
- Multiple ERT surveys were conducted to identify optimum spot for the placement of drywell, monitoring and vadose zone wells in Lower Umatilla basin.

- Water quality sampling for chemical fingerprinting, nutrients (NO3, NO2, NH3, TKN, PO4), nitrate and water isotopes, bioinformatics, trace metals, e. coli and physico-chemical parameters: temperature, pH, DO, ORP, EC, nitrate, turbidity, alkalinity.

Permitting and other activities

- Permitting of ASR injection.
- Permitting land easement.

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

1. We collaborated with Trevor McKellar and Mike Crimmins (both at University of Arizona) on the topic of high-irresolution grid-based simulation of soil water dynamics and drought.
2. Three MS students are now working on hydraulic property mapping.
3. One MS student is working on resolving input-data issues in SOLUS100 (oven-dry vs bulk density at 33 kPa)
4. One MS student is working on reducing data-storage requirements for hydraulic maps (terabytes to gigabytes).
5. One MS student is looking at the effect of soil organic matter dynamics on soil hydraulic properties using the OpenLandMap, SOLUS and Soil Gridsplus products.
6. Purchased an additional 75 Terabyte storage to serve as off-site backup of project products and to support the activities of PI and students
7. On request from some W-5188 members we included unsaturated hydraulic conductivity in the Rosetta 3 PTF (ongoing research, but almost completed)

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

- Developed and tested updated thermal property sensors, and completed laboratory calibration for integrated thermal sensing algorithms.
- Advanced time domain reflectometry waveform analysis for partially inserted sensor rods.

University of Nebraska (Aaron Daigh)

1. Produced vadose zone models from core samples underlying long-term crop production in Nebraska and performed virtual experiments to evaluate the long-term effects of N fertilizer application rates, crop rotations, and weather.
2. Initiated multi-month incubations for soil nitrogen mineralization kinetics of field samples to investigate spatial variability within map units.

3. Initiated site selections for subsurface electromagnetic imaging with tTEM and GPR on crop producers lands in Nebraska followed by scheduling of vadose zone and aquifer core sampling to the depth of refusal. Research is aimed at creating 3D geologic models and 3D vadose zone transport models of deep reduction zones that impact aquifer water quality.

Oklahoma State University (Tyson Ochnser)

- Held bi-monthly project meetings between our team, our research collaborators, and stakeholders within NRCS.
- Installed improved soil moisture sensors at all 120 Oklahoma Mesonet sites.

University of Kentucky (Ole Wendroth)

1. It is our goal to parameterize and set up the 3-D soil hydrologic model SWAT+ to represent surface and subsurface lateral flows. During this year, progress was made in delineating the field in Hydrological Response Units (HRUs) and parameterizing the model. We work closely together with the developers' group at Texas A&M University. Challenges remain with the variable rate irrigation system. The transfer of computer-generated irrigation apps to the pivot system is only partially functional. We work with the pivot irrigation manufacturer to troubleshoot the remaining issues.

2. A UAV-based thermal stress detection camera is used to identify zones of crop water stress. First experiments show spatial differences in water stress across the field. However, for scanning a field of 56 ha, four hours are needed. During these four hours, temporal changes of water stress can overwhelm spatial differences.

3. In the spectroscopic investigation of soil mineral nitrogen, basic experiments were focused on the spatial setup of measurements under lab conditions so that in the future, we can begin with field measurements. The current tasks are focused on separating the influence of soil water content on spectroscopic results from nitrate signals.

North Carolina State University (Josh Heitman)

1. We tested effects of biocrusts on water and ice content, and soil properties.
2. We constructed flexible models for soil thermal conductivity.
3. We tested approaches to account for effects of changes in density on soil hydraulic properties.
4. We evaluated management approaches to improve temperature and water conditions for crops.

North Dakota State University (Kang Liang)

- Conducted process-based modeling of hydrology and nitrogen transport using SWAT and regional climate models.
- Analyzed impacts of land use, crop management, and tillage practices on water quantity and quality.
- Evaluated model uncertainty, calibration strategies, and monitoring limitations.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

1. We (in collaboration with Josh Heitman at NCSU) investigated soil thermal conductivity.
2. We investigated soil electrical conductivity.
3. We investigated the field calibration of soil heat flux plates.
4. We calculated winter rye cover crop growth.
5. We tested for the optimum spatial resolution required to give the best gully erosion susceptibility in topographically different watersheds.
6. We established a continuous visual monitoring system to capture root development throughout the growing period, integrating soil water distribution measurements at multiple depths.

Virginia Tech (Ryan Stewart)

1. We have completed and published a set of experiments designed to characterize gas diffusion and hydraulic properties of soilless substrates commonly used in nursery production in the United States.
2. We collected soil and stormwater samples from utility-scale solar sites versus adjacent reference areas.
3. We continued our theoretical development of new models to describe infiltration in various soils, including heterogeneous and water-repellent conditions.
4. We performed laboratory measurements to quantify leaching dynamics of saltwater dredge materials.
5. We continued development on a new method to quantify hydraulic and physical properties of soils and soilless substrates using tension infiltrometer measurements.

University of Delaware (Yan Jin)

1. Collected monthly porewater samples from St. Jones Reserve, a coastal wetland, from piezometers installed at 30-cm and 120-cm depths at 4 locations along a salinity gradient.

2. Continuous monitored soil redox potential at 10, 50, 100, 150, and 200-cm depths, as well as pH, salinity, water level, and temperature at 60-cm depth at St. Jones Reserve, using in situ Pt-redox probes, HOBO pH sensors, and LTC sensors at 15-minute intervals; processed and integrated the resulting time-series datasets.
3. Analyzed porewater samples across tidal regimes and seasons for stable hydrogen and oxygen isotope composition (δ^2H, $\delta^{18}O$, $\delta^{17}O$).
4. Measured and integrated complementary physiochemical parameters (e.g., electrical conductivity, redox potential) to evaluate mixing and biogeochemical responses.
5. Developed an isotope-based end member mixing analysis (EMMA) framework incorporating both isotopes and salinity.
6. Designed and implemented the Evaporative Enrichment Index (EEI) to isolate non-conservative isotopic modification.
7. Applied statistical analyses to evaluate seasonal, tidal, and depth-dependent patterns in mixing and redox-sensitive chemistry.
8. Analyzed porewater samples from St. Jones Reserve for pH, EC, Eh, and chemical properties (e.g., various elements, ions and DOC) and for carbon utilization pattern and microbial enzyme activity (β-glucosidase and phosphatase).
9. Measured soil hydraulic properties of saline and non-saline soils in the laboratory under wetting-drying scenarios through evaporation experiments.
10. Measured water retention characteristics of three soil textures in the dry range of moisture content for saline and non-saline soil samples.
11. Performed extensive controlled-environment measurements of soil saturated hydraulic conductivity (Ks) to quantify salinity effects during initial exposure and following dilution/removal, and to evaluate the role of organic amendments in mediating these responses.
12. Procured an 8200-01S Smart Chamber and an LI-820 CO2 analyzer for laboratory-based soil column measurements of CO2 emissions, and assembled incubation bottle systems for indoor soil respiration experiments.
13. Collected and analyzed global datasets on soil organic matter chemical composition and coordinated with ERDC to obtain and analyze soil samples collected across the United States, thereby supplementing and improving global soil organic matter databases.

Conference Abstracts

1. Bradach, S. Yan Jin (2025) Tracing Tidal Influence: Using Stable Isotopes to Assess Porewater Chemistry in a Tidal Marsh. 2025 Kirkham Conference, Fukushima, https://scisoc.confex.com/scisoc/2025kc/meetingapp.cgi/Paper/164862
2. Joseph D'Agostino and Yan Jin, The influence of organic carbon on soil hydraulic responses during salinization, Soil Science Society of America Soil Physics and Hydrology Division CANV AS, November 9-12, 2025, Salt Lake City, Utah.

3. Liu, Y., & Chen, Y. Semiconducting Mineral-Driven Photoelectric Effects Under Sunlight Promote Microbial Colonization and Nitrate Reduction. CANVAS 2025, November 9-12, 2025, Salt Lake City, UT.
4. Naseri, M., D'Agostino, J. and Jin, Y. (2025). Effects of salinity and repeated drying on soil hydraulic properties: Experimental and modeling insights. Proceedings of CANVAS 2025, 9-12 November 9-12, 2025, Salt Lake City, Utah, USA.
5. Naseri, M. and Jin, Y. (2026). Drying-memory effects and texture-dependent salinity responses revealed by full-range measurements of soil hydraulic properties. EGU General Assembly 2026, 3-8 May 2026, Vienna, Austria.

University of Wisconsin-Madison (Jingyi Huang)

- Worked on research projects funded by USDA Hatch - Multistate W4188, NSF, and USDA NIFA programs
- Advising two Ph.D. students, two M.S. students, and one postdoctoral researcher and serving on the committee members of three Ph.D. and two M.S. students
- Teaching Soil Physics (Soil Science 622) and Using R for Soil and Environmental Sciences (Soil Science 585)
- Reviewed 45 manuscripts for various journals

Michigan State University (Jiquan Chen)

1. Initiated the integration of ecosystem flux data across southern Michigan to support AI-based prediction of crop production.

Michigan State University (Wei Zhang)

1. Program chair for the Soil Physics and Hydrology Division for ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025

Conference Presentations

1. Li, C., Q. Cao, Z.D. Hayden, K. Steinke, H. Li, and W. Zhang. 2025. Can soil amendments influence metallome in carrots (Daucus carota subsp. sativus)? ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025, Salt Lake City, UT. November 9-12 (oral presentation).
2. Cao, Q., H. Li, K. Steinke, Z.D. Hayden, C. Li, and W. Zhang. 2025. Carrot metallome is primarily controlled by growth stage rather than soil water conditions. ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025, Salt Lake City, UT. November 9-12 (oral presentation).

3. Benedict, A., Q. Yuan, H. Li, J. Bartz, and W. Zhang. 2025. Prion protein sorption to model mineral surfaces: A molecular dynamics study. ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025, Salt Lake City, UT. November 9-12 (oral presentation).
4. Zhang, W. 2025. Environmental contaminants in soil, water, and plant systems: One health perspective. ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025, Salt Lake City, UT. November 9-12 (oral presentation).
5. Li, R., J. Yi, H. Li, and W. Zhang. 2025. Predicting bioconcentration factors and concentrations of per- and polyfluoroalkyl substances in plants using machine learning. ASA, CSSA, SSSA International Annual Meeting, CANVAS 2025, Salt Lake City, UT. November 9-12 (oral presentation).
6. Zhang, W. 2025. Research trends on environmental contaminants: One health perspective. 2025 International Workshop on Agro-Environmental Health, Nanjing, China, October 11-14 (invited oral presentation).
7. Zhang, W. 2025. Environmental contaminants in soil, water, and plant systems:
8. One health perspective. Workshop on advancing tropical agriculture resilience and sustainable development in southeast Asia, Sanya, China, July 1-4 (invited oral presentation).
9. Zhang, W. 2025. PFAS in agriculture: what you should know. Great Lakes Crop Summit 2025, Mount Pleasant, MI, January 30, 2025.

University of Florida (Ebrahim Babaeian)

- Maintained and managed field experiments by installing and calibrating multiple in situ and proximal sensors (e.g., soil moisture, matric potential) along with remote sensing platforms to characterize soil water dynamics in Florida' sandy soils.
- Developed a deep learning framework (CNN-LSTM) to estimate surface and root-zone soil moisture by integrating multi-source, multi-scale ground-based and satellite remote sensing observations across the contiguous U.S.
- Designed deep learning models for short-, mid-, and long-term nowcasting and forecasting of soil moisture using long-term in-situ measurements and satellite observations (e.g., SMAP).
- Developed and evaluated a hybrid retrieval model that couples the tau-omega radiative transfer model with machine learning (XGBoost) to estimate surface, near-surface, and root-zone soil moisture in sandy agricultural agroecosystems in Florida.
- Taught Environmental Soil Physics to undergraduate and graduate students from diverse disciplinary backgrounds.

Connecticut Agricultural Experiment Station (Yingxue Yu)

- Investigated how soil solution interactions and eco-corona formation modify nanoplastics physicochemical properties, aggregation behavior, and transport dynamics.
- Quantified aggregation kinetics and colloidal stability of biodegradable and conventional nanoplastics under varying electrolyte conditions and ionic strengths.
- Demonstrated the role of soil solution chemistry, polymer bridging, and hetero-aggregation with soil colloids in controlling nanoplastics mobility.
- Evaluated the effects of weathering and soil solution exposure on nanoplastics surface charge, hydrophobicity, and transport behavior.
- Conducted controlled transport experiments under unsaturated flow conditions to assess ionic-strength-dependent aggregation effects.
- Quantified the impacts of tire wear particles (TWPs) on soil physical properties, including bulk density, water retention, field capacity, and plant-available water.
- Demonstrated that microplastic contamination alters soil–water relationships and water availability characteristics.
- Authored a comprehensive review synthesizing emerging challenges and research opportunities in vadose zone processes.

Texas A&M University (Briana Wyatt)

1. Monitored soil matric potential, groundwater level, deep soil moisture levels (neutron probe), canopy interception, and plant transpiration in the Post Oak Savannah.
2. Quantified soil hydraulic properties from soil samples collected in the Post Oak Savannah.
3. Applied soil hydraulic property models to estimate deep drainage and potential groundwater recharge under various land cover types above the Carrizo-Wilcox Aquifer.
4. Numerical modeling of the impacts of woody plant removal on groundwater recharge to the Carrizo-Wilcox aquifer.

Texas A&M University (Binayak P. Mohanty)

- Field monitoring and laboratory experiments were conducted at Texas Water Observatory sites under different land use land covers for improved understanding of soil moisture, temperature, aggregate stability, and carbon dynamics.
- We studied energetic cost of transporting water in soil-vegetation continuum. Self-similarity in water-carbon coupling across ecosystems was revealed. At leaf scale, this self-similarity behavior provides universal parameters to predict time series of photosynthesis and water use efficiency. At remote sensing scale, these self-similar forms bifurcate into conservative and aggressive water use strategies for ecosystems.
- Using thermodynamics principles and various satellite observations for evapotranspiration and surface soil moisture at the footprint scale, we developed a unified

framework of soil hydrology and energy balance coupling across multiple space-time scales.

- We provided a novel coherent theory on the dissipative energy barriers which decides the resilience potential of an ecosystem. These barriers are manifestation of lower bounds of entropy produced for unit anomaly transference from soil moisture to evapotranspiration.
- Using designed field and lab experiments, we studied organic and inorganic contaminants in various urban gardens of Texas. Data were analyzed using Graph Network. The findings led to better understanding of environmental and human health risks.
- -We evaluated soil moisture, ET, and GPP spatio-temporal structures and proposed upscaling schemes using ground, airborne, and satellite data.

Meetings attended

Kirkham Soil Physics Conference, Fukushima, Japan, August 18-22, 2025
Soil Science Society of America Annual Meeting, November 9-12, 2025.
American Geophysical Union Fall Meeting, December 15-19, 2025.

Book Chapters:

1. Mohanty, B.P. A Perspective: Climate Smart Decision Making in Agriculture for 21st Century:
2. Challenges and Opportunities using AI, in Sustainable Agricultural Development with Climate Smart Systems, Editor: Rabindra K Panda (Invited), Springer Nature, in Press.
3. Mohanty, B.P., and D. Mishra. Ecohydrology and the Water Cycle Across Scales: Scale and Spatial Heterogeneity in the Handbook of Terrestrial Ecohydrology, Editors: Bradford Wilcox, Heidi Asbjornsen, Keith Smettem, Irena Creed, Lixin Wang (Invited), Wiley, in Press.
4. Mohanty, B.P. and B. Chun. Soil Carbon in Grassland in Remote Sensing of Rangelands - Monitoring the Anthropocene, Editors: Opha Pauline Dube and John Isaac Molefe, (Invited), CSIRO Pub, in Press.
5. Mohanty, B.P., V. Sehgal, and D. Mishra. Satellite Remote Sensing of Rangeland Fresh Water Resources in Remote Sensing of Rangelands - Monitoring the Anthropocene, Editors: Opha Pauline Dube and John Isaac Molefe, (Invited), CSIRO Pub, in Press.

Abstracts:

1. Mohanty, B.P., Multi-Scale Soil Moisture Dynamics and its Applications, Soil Science Society of America Annual Meeting Abstract, 2025.
2. Mishra, D., V. Sehgal, and B.P. Mohanty, Can We Estimate Active Root Zone Depth Using Remote Sensing Data? AGU Fall Meeting Abstract, 2025.
3. Mohanty, B.P., and D. Mishra, SMAP to NISAR: Bridging Spatial and Temporal Scales for Heterogeneity-Informed “any scale” Soil Moisture Product, AGU Fall Meeting Abstract, 2025.

4. Mohanty, B.P., A Cross-scale Perspective on Ecosystem Sensitivity from the Lens of Soil Moisture, AGU Fall Meeting Abstract, 2025.
5. Mishra, D., R. Singh, B. Chun, N. Gollakota, S. Calabrese, B.P. Mohanty, Assessing the Impact of Agricultural Practices on Surface Energy Balance in Central Texas, AGU Fall Meeting Abstract, 2025.
6. Sedaghatdoost, A., B.P. Mohanty, and D. Dwivedi, Hydrological Forcing, Soil Stratigraphy, and Microbial Pathways Drive Depth-Dependent Redox Dynamics in the Vadose Zone, AGU Fall Meeting Abstract, 2025.
7. Chun, B., B.P. Mohanty, A.V.M. Ines, and S. Slack, A New Modeling Framework for Estimating Ecosystem Respiration Under Different Land Uses, AGU Fall Meeting Abstract, 2025.
8. Kocian, L., B.P. Mohanty, and A. Sharif, Tracing Cadmium in Texas Urban Gardens: Isotope Fingerprinting, Transport Modeling, and Bioavailability Assessment, AGU Fall Meeting Abstract, 2025.

Invited Presentations:

1. Invited Speaker, Characterizing Large-scale Preferential Flow across Continental United States, Challenges and Opportunities in Porous Media Multiphase Flow and Contaminant Transport Research - International Conference in honor of “Rien” van Genuchten, on the occasion of his 80th birthday, Rio De Janeiro, Brazil, May 7-9, 2025.
2. Distinguished Keynote Speaker, Role of Soil Moisture in Agriculture, Hydrology, and Land-Atmosphere Interaction, Symposium on Satellite Utilization in Agriculture and Forestry, Kyungpook National University in Daegu, Republic of Korea, August 11, 2025.
3. Invited Speaker, Multi-Scale Soil Moisture Dynamics and Its Applications, From Soil Hydrology to Microbial Water Quality in 50 Years: Commemorating Yakov Pachepsky’s Research Interactions between Physics and (Micro)Biology: Water, Chemistry, and Biota, Soil Science Society of America, Salt Lake City, Utah, November 9, 2025.
4. Invited Speaker, A Cross-scale Perspective on Ecosystem Sensitivity from the Lens of Soil Moisture, American Geophysical Union Fall Meeting, New Orleans, Louisiana, December 17, 2025.

University of Hawai‘i at Mānoa (Jing Yan)

1. Conducted a comprehensive literature review to synthesize existing hydraulic soil measurements for soils in the tropical regions of Hawai‘i, drawing from historical soil surveys, peer-reviewed publications, dissertations, and public technical reports
2. Initialized data governance procedures for soil-hydraulic data curation, including metadata standards, quality-control protocols, and reproducible data-management workflows

3. Collected representative soil samples from agricultural fields in Oahu, Hawaii, i.e., Oxisols, and performed laboratory experiments and developed critical procedures to study soil microbial activities and their feedback mechanisms, including soil sterilization, fungal inoculation, and morphological characterization
4. Performed soil hydraulic characterization experiments, including soil water retention measurements, evaporation tests, and wettability tests, to evaluate how fungal inoculation and microbial development influence soil physical and hydraulic properties

University of Tennessee-Knoxville (Xi Zhang)

1. Studied soil water dynamics under different cover cropping management practices.
2. Investigated the role of biodegradable microplastics in shaping subsurface structure and hydrologic processes and its implications for the migration of microplastics in the soil-groundwater environment.
3. Served as chair for USDA-NIFA NC 1178 Multistate Project: Land Use and Management Practice Impacts on Soil Carbon and Associated Agroecosystems Services.
4. Served on American Geophysical Union Soils Processes and Critical Zone Technical Committee.
5. Served as associate editor for Soil Science Society of America Journal and Agrosystems, Geosciences and Environment
6. Served on Editorial Board for Soil and Tillage Research and Earth Critical Zone.
7. Attended ASA-CSSA-SSSA International Annual Meeting (Salt Lake City, UT. Nov. 9-12, 2025).

Conference Abstracts

1. Peng, R., G. Feng, X. Zhang and G. Bi. Temporal changes in soil hydraulic properties under cover crops and manure management in a reduced tillage system. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Poster)
2. Dai, W., G. Feng and X. Zhang. Microplastic effects on soil structure and subsurface water dynamics: evidence from a column study. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Poster)
3. Dai, W., G. Feng and X. Zhang. Soil aggregation responses to sustainable agricultural practices in the southeastern United States. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Oral)
4. Vital, S., G. Feng, H. Tewolde, X. Zhang, J. Brooks and D. Morin. Spatial configuration of cover crop mixtures with poultry litter: assessing net biodiversity effects on residual nutrient cycling and cotton productivity. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Oral)
5. Vital, S., G. Feng, H. Tewolde, X. Zhang, J. Brooks and D. Morin. Cover crops and poultry litter drive soybean nutrition, yield, and soil nutrient dynamics across planting

windows. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Oral)

6. Vital, S., G. Feng, W. Dai, A. Adeli, D. Miles, J. Brooks, X. Zhang and D. Morin. Linking soil health, greenhouse gas fluxes, and crop yield: decoding management impacts in cover-crop systems. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Oral)
7. Vital, S., S. Xu, M. Geza Nisrani, P.J. Sexton, N. Ghimire, C. Graham, L. Xu, X. Zhang and J. Wu, J. Response of soil macropores, hydro-physical properties, water dynamics, and carbon accumulation to crop rotations and cover cropping under no-till management. ASA-CSSA-SSSA Annual Meeting, Salt Lake City, UT. Nov. 9-12, 2025. (Oral)

Montana State University (Jack Brookshire)

1. Conducted field research campaigns in central Montana investigating effects of conifer encroachment and fire on soil biogeochemistry
2. Submitted 3 grant proposals to federal agencies

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

- Developed materials derived from agricultural byproducts and invasive plant species to remove antibiotic resistance genes (ARGs) from wastewater.
- Demonstrated the feasibility of repurposing crop residues and waste materials into cost-effective wastewater treatment media.
- Investigated nature-based and waste-derived solutions for mitigating environmental risks associated with wastewater reuse in agriculture.
- Developed a mobile soil sensing platform for high-resolution soil characterization in micro-irrigated specialty crop systems.
- Designed and implemented sensor data post-processing and fusion algorithms for on-the-go soil mapping under non-uniform wetting conditions.
- Generated detailed soil property maps to support precision irrigation and salinity management in orchard systems.
- Evaluated sensor-based approaches for improving soil spatial information in drip and micro-sprinkler irrigated fields.

Milestones

<u>Objective 1:</u> Connect New Understandings of Storage and Transport of Mass and Energy to Assess Environmental Change

University of California, Riverside (Hoori Ajami)

1. Improve understanding of groundwater recharge processes in mountain catchments using streamflow recession analysis and integrated hydrologic models
2. Understand processes that control preferential flow

University of California, Riverside (Jirka Šimůnek)

We continue to expand the capabilities of the HYDRUS modeling environment by developing specialized modules for more complex applications that cannot be solved using its standard versions. The standard versions of HYDRUS, as well as its specialized modules, have been used by me, my students, and my collaborators in multiple applications described below.

Hydrological Applications:

1. Zhou et al. (2025) used the numerical HYDRUS-1D model, a Bayesian probabilistic approach, and novel towed transient electromagnetic (tTEM) data to determine the transport of pesticides (especially their maximum transport depths (MTDs)) in 70-m-thick soil profiles in response to large water applications (MAR).
2. Zhou et al. (2025) assessed using the numerical HYDRUS-1D model recharge travel times in multilayered soil profiles influenced by preferential flow.
3. Fachi et al. (2025) assessed the use of bimodal water retention functions for stony soils and their determination using curve fitting and inverse modeling.
4. Ghasemnezhad et al. (2025) developed a novel copula framework for evaluating depth-stratified water quality monitored in water reservoirs.
5. Mardy et al. (2025) used three machine learning models, i.e., Random Forest (RF), Multilayer Perceptron Neural Networks (MLP-ANN), and Kolmogorov-Arnold neural networks (KANN), and CMIP6 models to downscale precipitation.
6. Nikoo et al. (2025) developed a two-dimensional hydrodynamic model, i.e., CE-QUAL-W2, to evaluate future projections of thermal and chemical stratifications in a reservoir under the impact of climate change.

Particle Transport:

7. Guo et al. (2025) introduced an optimization generator of synthetic DNA sequences (guided by seven principles, which enable the concurrent generation of multiple

sequences with enhanced stability, specificity, and detectability) for the rational design of environmental tracers.

8. Wang et al. (2025) used a synthetic DNA labeling method for high-resolution characterization of the size exclusion effect on the transport of a low-concentration mixed-size colloids in porous media.
9. Li et al. (2025) used synthetic DNA fragments (to compare with traditional dye tracers) as high-resolution tracers for hydrological parameter inversion (using tracer travel-time inversion (TTTI) and a two-step approach combining TTTI with hydraulic tomography).
10. Wang et al. (2025) evaluated the use of a synthetic DNA labeling approach for high-resolution characterization of mixed-size colloid transport in porous media. A synthetic DNA-labeling/qPCR approach to distinguish mixed colloids transport in porous media was developed. The findings of the study demonstrated that (a) mixed colloid transport cannot be predicted from monodisperse system behavior and (b) high-resolution tracking is essential for accurate mixed colloid transport prediction. This work provides critical insights for assessing colloid-facilitated contaminant transport in groundwater systems.
11. Behnam et al. (2025) studied the transport and retention of acid-modified biochar nanoparticles and their role in the co-transport and remobilization of lead in a saturated sand column.HYDRUS-1D simulations using depth-dependent and Langmuirian models were applied to evaluate nanoparticles' retention. Since biochar nanoparticles increased Pb2+ mobility in porous media, the authors argued that adopting policies that eliminate such conditions is essential for the environment.

HYDRUS Papers:

12. 16. Rahman et al. (2025) developed a new externally coupled, physically-based multi-model framework for simulating subsurface and overland flow hydrological processes on hillslopes. They used three well-established numerical models (i.e., HYDRUS, Kineros, and Modflow), each very good at what it does, and combined them without any modifications into a single powerful package that is highly computationally efficient, very flexible, and capable of considering water flow and solute transport in both overland and subsurface environments.
13. 17. Brunetti et al. (2025) modified HYDRUS-1D to consider dynamic changes in soil hydraulic properties in response to tillage and follow-up consolidation. The model was first verified against observations of the joint temporal change in soil bulk density and hydraulic properties after tillage in a bare-field soil in the USA. Next, Bayesian inference was combined with temporally sparse volumetric water content measurements collected from two agricultural hillslopes in Czechia to statistically compare the dynamic model with its static counterpart.
14. 18. Brunetti et al. (2025) developed a unified physically-based model to simulate water and carbohydrates allocation along the soil-fruit axis by coupling the HYDRUS-1D

model with the Sugor model. The model was calibrated and validated using experimental data on tomato crops under varied irrigation conditions.

15. 19. Oad et al. (2025) incorporated an option to account for horizontal aquifer flow in a vertical vadose zone model (HYDRUS-1D) to simulate natural groundwater table fluctuations. The results obtained by the modified HYDRUS-1D model were compared with reference simulations using HydroGeoSphere (HGS), which explicitly represents 2D flow in the unsaturated and saturated zones in a vertical cross-section of a strip aquifer, including evapotranspiration and plant water uptake.

Other Papers:

16. 20. Urdiales et al. (2025) evaluated transport mechanisms of the anthropogenic contaminant sulfamethoxazole in volcanic ash soils at equilibrium pH using the HYDRUS-1D model.
17. 21. Hao et al. (2025) evaluated dynamic processes of CO2 migration as influenced by water and temperature in the arid sandy shrubland vadose zone using the SOILCO2 module of HYDRUS. The study highlighted the importance of understanding the water-heat-carbon coupling mechanisms in the root zone, which is crucial for elucidating soil carbon emission dynamics.
18. 22. Daraei et al. (2025) evaluated the effects of montmorillonite amendments on quinoa growth, and water flow and solute transport in sandy loam and loam soils. It is demonstrated that the nano-clay amendment significantly alters the soil's physical and chemical properties, thereby affecting solute transport and the photosynthetic parameters of the quinoa cultivar.

University of California, Davis (Thomas Harter)

1. Completed seventh year of long-term water and nitrogen flux monitoring in a 140 acre almond orchard, at the land surface, in the vadose zone, and in groundwater
2. Completed first intensive analysis of deep vadose zone monitoring system in irrigated tomato-field crop rotation.

University of California, Davis (Majdi Abou Najm)

1. Conducted field experiments evaluating crop responses to altered light and shading regimes, quantifying impacts on yield and water use efficiency.
2. Developed and operated an agrivoltaics research facility enabling investigation of coupled soil–water–energy–plant interactions.
3. Advanced understanding of water and solute transport processes through modeling studies of nitrate leaching and soil infiltration.

4. Improved mechanistic descriptions of infiltration and flow under complex soil conditions, including fractional wettability.
5. Contributed syntheses linking energy systems (photovoltaics) with soil carbon and environmental processes.

University of California, Davis (Helen E. Dahlke)

This research significantly advanced the fundamental understanding of water, solute, and reactive nitrogen transport in heterogeneous and structured soil–vadose zone systems, particularly under extreme hydrologic perturbations associated with Agricultural Managed Aquifer Recharge (Ag-MAR).
Using a combination of field observations and physically based modeling, we quantified how preferential flow, mobile–immobile domain exchange, and soil texture heterogeneity regulate water and nitrate transport during large, short-duration recharge events. Dual-porosity HYDRUS-1D simulations revealed that nitrate transport under Ag-MAR cannot be described adequately by equilibrium or piston-flow assumptions. Instead, nitrate fate is governed by non-equilibrium flow and transport, where rapid bypass flow through preferential pathways co-occurs with slow exchange with immobile pore domains that store legacy nitrate.

The results demonstrated that mobile–immobile mass transfer processes dominate nitrate fate in fine-textured profiles with large legacy nitrate pools, whereas reaction kinetics exert greater control in coarse-textured profiles where preferential flow is strong and residence times are short. This distinction clarifies when nitrate transport is transport-limited versus reaction-limited, a long-standing challenge in vadose zone hydrology and biogeochemistry.

The work further improved understanding of deep vadose zone processes and linkages to groundwater by demonstrating how nitrate mobilized during Ag-MAR exhibits shallow dilution, delayed breakthrough at depth, pronounced first-flush behavior, and long recession tails. These dynamics underscore the importance of deep unsaturated zone storage as both a buffer and secondary source of nitrate, with implications for groundwater vulnerability assessments.

In addition, the research advanced understanding of coupled water–solute–biogeochemical processes by quantifying how Ag-MAR alters soil redox conditions, nitrogen transformations, and post-flooding mineralization dynamics. The findings show that wetting–drying cycles associated with recharge can stimulate mineralization and nitrification following drainage, partially offsetting nitrate losses incurred during flooding.

Together, these results directly address W5188 priorities related to preferential flow (1.1), water and solute transport in heterogeneous systems (1.6), and deep vadose zone processes and groundwater linkages (1.7), while contributing new mechanistic insights into reactive transport under extreme hydrologic forcing.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

1. Model evaluation for water infiltration into hydrophobic soil using laboratory-scale measurements.
2. Improved model to simulate water infiltration, redistribution and evaporation for arid soils.

Washington State University (Markus Flury and Joan Wu)

Soil compaction and soil organic matter are critical factors influencing crop growth and soil health. We investigated a 26-year field experiment on fine sandy loam soil in Washington State, USA, involving three biosolids application rates (0, 4.7, and 10.0 Mg/ha) applied every four years in a winter wheat-fallow rotation. Compaction reduced porosity and hydraulic conductivity. While compaction impacted soil physical and hydraulic properties, biosolids had limited effects. Contrary to our expectations, no interaction between biosolids application and compaction treatments was observed. Despite numerous benefits of increased soil organic matter with biosolids application, no increased resistance to and recovery from soil compaction was observed.

When studying the impacts of microplastics on compaction, we found that soil compression was significantly affected by microplastic types, size, and concentrations. Granular microplastics increased the void ratio uniformly within the applied stress whereas fibrous microplastics increased the void ratio much more at low stress than at high stress. As a result, fibrous microplastics significantly increased the compression index with increasing microplastics concentration. Granular microplastics decreased the swelling index, making soil less resilient against compaction. However, soil structure, water holding characteristics, and water and gas permeability were not significantly affected.

Oregon State University (Salini Sasidharan)

To improve fundamental understanding of preferential flow and its role in biogeochemistry (a-b) we performed water injection and tracer experiment (August 2025), including data collection of various water quality (nitrate, EC, oxyanion concentration) and water quantity parameters (volumetric water content, resistivity tomograms) and techniques. HYDRUS 2D simulations to replicate field observations are under development.

To improve fundamental understanding of dynamic changes in soil properties (items c-d) laboratory column experiments and a novel 'Guard' column proposal was tested under field-scale drywell recharge experiment. Findings provide a cost-effective pre-treatment for clogging.

To improve fundamental understanding of Deep vadose site processes and linkages to groundwater (f-g): subsurface properties and heterogeneity of the DeepVadoSense site in Lower Umatilla basin was completed and the optimum locations for drywell, DeepVadoSense and monitoring well placement were confirmed last quarter.

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

1. We improved maps of soil hydraulic properties for the contiguous United States using the SOLUS100 product of the NRCS. The resulting products also include complete covariance matrices that would allow uncertainty assessments of hydraulic properties as well as derived products such as uncertainty in water dynamic simulations with Hydrus-1D for the purposes of mapping water resources and drought mitigation.
2. Started work on a SOLUS-related, but global, product that provides data for 20 billion points globally with a resolution of 120 meters to 30 meters.
3. We demonstrated conclusively that greater than 50% of the soils exhibit bimodality (rather than unimodality) in their retention curves. The bimodality is driven by soil structure and soil texture.

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

1. Developed improved model for soil water characteristics to better represent dry-end behavior.

University of Nebraska (Aaron Daigh)

1. Identified prospective reduction zones in deep vadose zone and shallow aquifer formations and obtained geophysics surveys (tTEM, GPR), deep vadose zone cores, and completed core characterizations.
2. Obtained soil samples and completed soil characterizations for research on soil and nitrogen spatial variability of nitrogen mineralization kinetics.

Oklahoma State University (Tyson Ochnser)

No milestones for this objective.

University of Kentucky (Ole Wendroth)

1. For relevant computer simulation results with the SWAT+ model, the goal of our study is to implement site-specific management decisions into the model input so that farmers' operations and management decisions can realistically be simulated and scenarios be developed by fall 2026.
2. The goal of UAV-based remote sensing is to convert air-borne spatial patterns of crop status and vegetation indices into reflections of crop growth status and water and nutrient availability by October 2026.
3. An essential next step in the quantification of soil nitrate concentration will be the technological approach to collect spectroscopic data at different soil depths because soil surface nitrate concentration does not reveal sufficient information for management decisions within this year.

North Carolina State University (Josh Heitman)

In cold-winter drylands, a substantial portion of soil water remains unfrozen throughout the frozen period despite subzero temperatures. This unfrozen water critically governs winter hydrological, thermal, and ecological processes. While biocrusts are well-known to regulate soil water dynamics during warm and wet seasons, their effects during cold periods remain largely unknown. We found that biocrusts regulated temporal and depth dynamics of unfrozen soil moisture during winter, and these effects depended on soil type. Biocrusts decreased unfrozen soil water storage in aeolian sand but increased it in loess soil. These contrasting effects fundamentally stemmed from biocrusts-induced changes in soil pore structures. Compared to bare soil, biocrusts decreased porosity within most surface layers (1–4 cm) of aeolian sand, while increasing it within surface loess soil (0–4 cm). Importantly, biocrusts-induced alterations in unfrozen moisture further led to increased temperature, shortened frozen period, and reduced freezing depth in aeolian sand, whereas opposite consequences occurred in loess soil. Overall, our findings highlight the critical role of biocrusts in regulating soil water dynamics during frozen periods, which could have implications for erosion processes, carbon emissions, plant phenology, and ecosystem productivity in cold-winter drylands.

North Dakota State University (Kang Liang)

1. Quantified soil water, streamflow, and nitrate transport mechanisms across agricultural watersheds.
2. Improved representation of soil-water-nutrient processes in the SWAT model.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

1. Soil thermal conductivity (λ) relates directly to conduction heat transfer in soil. Although numerous models have been developed to estimate soil thermal conductivity, their applicability is often limited to specific types of soils. Recognizing the similarity between the soil water retention curve and the λ versus water content (θ) curve, Lu and Dong presented a λ(θ) model, which can provide accurate λ estimates for various soils. However, the model does not converge to the proper thermal conductivity value of a saturated soil (λsat) when saturation approaches 1. In this study, we develop a modified form of the Lu and Dong (MLD) model to estimate λ as a function of θ. Additionally, we present a neural network (NN) approach to estimate parameters of the MLD model using soil porosity, sand, silt, and clay contents, as well as the thermal conductivity of soil solids (λs) as input features. The neural network is trained to optimize the hyperparameters, which are used to establish the NN-MLD model after the hyperparameter tuning process is completed. The NN-MLD model is then tested with an independent testing dataset and compared with five pre-existing models taken from the literature. Results show that the NN-MLD model outperforms the other models across four error metrics with a root mean square error (RMSE) of 0.157 W m-1 K-1, a mean absolute error (MAE) of 0.098 W m-1 K-1, an Akaike's information criterion (AIC) of -1700 and a coefficient of determination (R2) of 0.94. In comparison, the other models produce λ estimates with RMSEs ranging from 0.298 to 0.322 W m-1 K-1, MAEs from 0.194 to 0.210 W m-1 K-1, AICs from –1111 to -1038 and R2 from 0.76 to 0.79. In addition, error analysis across varying degrees of saturation (S) reveals that the NN-MLD model consistently outperforms the other models across the entire range of saturation levels. Its superiority over the other models is most pronounced at medium levels of saturation, where the other models yield RMSEs and MAEs values three times larger than those of the NN-MLD model.

2. Electrical conductivity, σ, has been widely used to estimate hydraulic conductivity in porous media as well as to interpret subsurface low- and high-conductivity zones. σ in a porous medium is impacted by the complicated relationship between the surface conductivity of solids, as the low-conductivity component which is significant at dry conditions, and bulk conductivity through the pore space, as the high conductivity component. As water saturation increases from completely dry to fully saturated, the effect of the bulk conductivity on electrical conductivity substantially increases. In this study, for the first time, we apply a percolation-based effective-medium approximation (P-EMA) to describe the saturation dependence of σ in porous media with significant surface conduction. The proposed P-EMA model estimates are compared to 16 data sets including three numerically simulated sets and thirteen measured sets. There is substantial agreement between the theory and the data, with scaling exponents ranging from 0.18 to 2.39, indicating non-universal behavior. The saturation-dependent σ values

of packed clay loam soil samples are estimated with the P-EMA model. The P-EMA estimated values are in reasonable agreement with the measured values.

Virginia Tech (Ryan Stewart)

1. To collect data from our new hysteresis quantification system, by June 2026.
2. To publish the results of a field study on infiltration and ponding in various landscapes of Virginia, including areas developed with utility-scale solar, by July 2026.

University of Delaware (Yan Jin)

- Analyses of porewater samples collected from our long-term field site showed that the forest location exhibited higher microbial diversity and activity, whereas wetland soils preserved robust carbon metabolic functionality for complex substrates despite the observed lower diversity and activity. Further, microbial carbon utilization patterns and diversities are stable in deep layers, whereas shallow layers varied due to the frequent water exchange with the nearby creek driven by tidal influences.
- Completed multi-season porewater sampling across a forest–marsh–channel transect.
- Quantified spatial and temporal variability in porewater mixing under saltwater intrusion.
- Established and validated column-scale experimental systems simulating sea-level–driven saltwater fluctuations, including the deployment of redox, conductivity, and temperature sensors, enabling controlled measurements of soil carbon emissions under varying hydrological conditions.

University of Wisconsin-Madison (Jingyi Huang)

No milestones for this objective.

Michigan State University (Jiquan Chen)

1. To develop an AI-based platform that helps farmers identify alternative management practices for building resilient agricultural systems.

Michigan State University (Wei Zhang)

1. Completed the training of machine learning models for predicting plant uptake of PFAS
2. Developed molecular dynamics models for studying prion fibrils with aromatic carbon surfaces
3. Revealed that metallomes of carrot and wheat are mainly controlled by plant growth stages

University of Florida (Ebrahim Babaeian)

No milestones for this objective.

Connecticut Agricultural Experiment Station (Yingxue Yu)

We investigated how interactions with soil solution and associated eco-corona formation modify the physicochemical properties, aggregation behavior, and transport of nanoplastics in terrestrial systems. Using nanoplastics derived from both a soil-biodegradable polymer (poly(butylene adipate-co-terephthalate), PBAT) and conventional plastics (polyethylene, polypropylene, and polystyrene), we examined aggregation kinetics, colloidal stability, and transport under controlled electrolyte conditions and unsaturated flow. In electrolyte solutions without soil solution, nanoplastics aggregated more readily in $CaCl_2$ than in NaCl, reflecting the role of divalent cations in destabilization. The addition of soil solution promoted nanoplastics aggregation, producing larger aggregates despite minimal changes in critical coagulation concentrations, driven by eco-corona formation, polymer bridging, patch-charge interactions, and hetero-aggregation with soil colloids. Weathering and soil solution exposure altered surface charge and hydrophobicity, generally reducing zeta potential differences and contact angles among different polymer types, with PBAT exhibiting distinct charge responses relative to conventional plastics. Transport experiments under unsaturated conditions showed limited effects at low ionic strength but enhanced aggregation at higher ionic strength. Collectively, these results demonstrate that natural surface modifications induced by soil solution and weathering can substantially alter nanoplastics stability, surface properties, and transport behavior, emphasizing the need to account for eco-corona formation and soil chemical complexity when assessing the environmental fate of nanoplastics in terrestrial environments.

Texas A&M University (Briana Wyatt)

1. Estimate deep drainage under various land cover types above the Carrizo-Wilcox Aquifer.

Texas A&M University (Binayak P. Mohanty)

1. We refined the understanding of land–atmosphere feedbacks and improving their predictions under future climate scenarios.
2. We estimated two emergent properties of the SM-ET coupling: active root zone depth supporting ET, and the characteristic transit timescales over which soil moisture is lost to atmosphere
3. We discovered that ecosystem tipping characteristics are defined by intensity, frequency, and duration of surface soil moisture excursions from wet- to dry-average state.

4. A key finding show that soil moisture tipping characteristics capture soil-vegetation-climate coexistence patterns within global biomes.

University of Hawaiʻi at Mānoa (Jing Yan)

1. Completed a comprehensive literature review synthesizing current knowledge on soil hydraulic behavior in tropical environments, with specific emphasis on Hawaiian soils and management contexts.
2. Established and documented a data governance framework to ensure consistent data handling, transparency, and long-term usability across all project datasets.
3. Developed standardized metadata protocols for essential matrix variables related to soil hydraulic, physical, chemical, biological, and environmental characteristics.
4. Initiated systematic curation of soil datasets, integrating preliminary physical, chemical, biological, hydraulic, and environmental data into a unified, quality-controlled structure.

University of Tennessee-Knoxville (Xi Zhang)

1. Improved mechanistic understanding of how cover crops influence subsurface hydrologic processes in agroecosystem.
2. Quantified the responses of soil physical structure and hydraulic properties to biodegradable microplastics.

Montana State University (Jack Brookshire)

1) Our research in rangelands of central Montana indicate that conifer woody plant encroachment (WPE) profoundly influences soil physical and biogeochemical properties and nutrient availability. Across >100 plots in open rangeland and under conifers, WPE is associated with significantly higher shallow mineral soil (0-5 cm) C and N concentrations. For C, this effect seems to persist across areas of dominated by C3 or C4 photosynthetic pathways. While forage species in our study area are dominated by C3 grasses, analysis of the distribution of soil d13C, a reliable signature of the contribution of C4 grasses (e.g., > -20 ‰), shows that soil C is consistently higher under conifers than in grasslands regardless of grass functional type. Further, despite overall lower bulk soil N in shallow grassland soils, analysis of d15N reveals a clear signature of WPE on soil N cycling and availability. Across global soils, bulk soil d15N is strongly linked to plant mycorrhizal type (AM> ECM) and inorganic nutrient availability. ECM plants strongly discriminate against 15N thus producing depleted isotope signatures and higher d15N is also generally associated with higher inorganic N bioavailability and gaseous losses. Thus, although shallow bulk soil organic N may accumulate under conifers, it may be less available to plants, particularly forage species.

In contrast to our findings of the effect of WPE on shallow soils, evidence from soil pit (0-50 cm depth) data collected under pure stands of conifer and adjacent open grassland tell a different story. We find that WPE is associated with sharp declines in mineral soil bulk density, pH, and soil N concentrations and pools while effects on soil C are less clear. Declines in bulk density under conifer encroachment have potentially large implications for water drainage and availability and grassland establishment during post-fire succession. Lower soil pH under conifers than grassland vegetation is consistent with acidification via enhanced carbonic acid production or cation redistribution by trees. The strong decreases in soil N under conifers results in coherent increases in the C:N ratio of SOM with depth, which is a key indicator of microbial N availability and carbon stability. Together, these results suggest that conifer WPE has penetrating effects on soil health that may have long-lasting effects on grassland forage recovery and raise fundamental questions as to the fate of soil N under increasing WPE.

Our growing body of evidence from the MMRB is that WPE has pronounced effects on soil biogeochemistry. What happens when we reintroduce fire? Our first studies in the area compared soils that had experienced long-term WPE but had not burned in recorded history to those that had experienced multiple severe (high mortality stand-replacing) wildfires since the 1980's. As part of a global comparison of the effects of repeated fire on forest and savanna ecosystems, we found that 1) soil inorganic N availability was significantly lower under conifers than in open grassland (consistent with N isotope findings above) and 2) repeated fire in formerly conifer encroached grassland strongly decreased bulk soil C and N and microbial enzyme activities that drive detrital C and N decomposition. Much of this effect was attributed to decreased woody litter inputs to soils over time.

1. In response to increasing WPE in our study area, the BLM has been conducting prescribed fires since 2014. We coordinated with the BLM and joint fire services to conduct a large scale before-after-control-impact (BACI) experiment on the vegetation and biogeochemical effects of fire reintroduction to a study unit that had not burned for at least 100 years. To do this, we established twenty-five 400 m2 plots prior to the fire for long-term monitoring of stem structure and demography and soil biogeochemical cycling. The low to moderate-intensity fire resulted in >30% mortality of overstory trees and 98% mortality of understory saplings. In contrast to the effects of repeated severe fire, we observed increases in surface soil C and N after the fire. Further, we found that a significant fraction of the new C influx was in the form of pyrogenic organic carbon (PyOC), a highly stable and persistent form of organic carbon in soil. These results offer the possibility that prescribed fire may offset some C losses to the atmosphere and conifer-induced N depletion from soils.

2. Rangelands provide significant environmental benefits through many ecosystem services, which may include soil organic carbon (SOC) sequestration. However, quantifying SOC

stocks and monitoring carbon (C) fluxes in rangelands are challenging due to the considerable spatial and temporal variability tied to rangeland C dynamics as well as limited data availability. We developed the Rangeland Carbon Tracking and Management (RCTM) system to track long-term changes in SOC and ecosystem C fluxes by leveraging remote sensing inputs and environmental variable data sets with algorithms representing terrestrial C-cycle processes. Bayesian calibration was conducted using quality-controlled C flux data sets obtained from 61 Ameriflux and NEON flux tower sites from Western and Midwestern US rangelands to parameterize the model according to dominant vegetation classes (perennial and/or annual grass, grass-shrub mixture, and grass-tree mixture). The resulting RCTM system produced higher model accuracy for estimating annual cumulative gross primary productivity (GPP) ($R2 > 0.6$, RMSE <390 g C m^{-2}) relative to net ecosystem exchange of CO2 (NEE)($R2 > 0.4$, RMSE <180 g C m^{-2}). Model performance in estimating rangeland C fluxes varied by season and vegetation type. The RCTM captured the spatial variability of SOC stocks with $R2 = 0.6$ when validated against SOC measurements across 13 NEON sites. Model simulations indicated slightly enhanced SOC stocks for the flux tower sites during the past decade, which is mainly driven by an increase in precipitation. Future efforts to refine the RCTM system will benefit from long-term network-based monitoring of vegetation biomass, C fluxes, and SOC stocks.

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

1. Conversion of agricultural waste and invasive plants into materials for wastewater treatment. Antibiotic resistance genes (ARGs) in wastewater represent an environmental health threat to land irrigated with treated wastewater. Removing these materials from wastewater is of critical importance to mitigate risks of wastewater reuse in agriculture. ARS researchers in Riverside, California, produced materials made from agricultural byproducts (nut shells, orange peel, manure, wood waste) and an invasive plant species (black mustard), and demonstrated the ability to effectively remove genetic material, such as ARGs, from water. This work provides a potentially cost-effective and environmentally friendly way to repurpose crop waste and invasive plant species into a material for wastewater recycling.

Objective 2: Develop and Test New Methods and Models to Improve the Quality of Soil Information and Knowledge

University of California, Riverside (Hoori Ajami)

1. Develop a new pedo-transfer function for hydrologic and Earth System Models
2. Assess impacts of roots on soil structure and hydraulic parameters

University of California, Riverside (Jirka Šimůnek)

No milestones for this objective.

University of California, Davis (Thomas Harter)

- Initiated phase 2 vadose zone modeling of pre- and post-implementation nitrate leaching, over an 80 year period at a California nut crop site
- Initiated phase 2 groundwater modeling of the heterogeneous aquifer conditions under a well-instrumented field site to assess monitoring well network source areas and long-term dynamics of nitrate pollution under changing fertilization practices

University of California, Davis (Majdi Abou Najm)

- Advanced mechanistic understanding of soil water infiltration through development and evaluation of conceptual and physics-based infiltration models.
- Developed modeling frameworks describing water flow under complex soil conditions, including fractional wettability.
- Quantified controls on nitrate leaching risk using process-based vadose zone modeling approaches.
- Contributed comprehensive syntheses addressing major challenges and emerging research needs in vadose zone processes.
- Improved interpretation of soil hydraulic behavior through critical evaluation of model selection and parameterization strategies.

University of California, Davis (Helen E. Dahlke)

This research translated fundamental soil physics concepts into actionable insights for groundwater recharge design, nitrogen management, and soil health protection under Ag-MAR.

Using a calibrated DSSAT cropping system model, we evaluated how Ag-MAR timing, duration, and intermittency influence soil water storage, nitrate leaching, effective mineralization, and growing-season water and nitrogen availability. Results demonstrated that intermittent flooding produces the greatest nitrate leaching, driven by repeated wetting–drying cycles that enhance nitrogen mineralization followed by rapid downward transport. In contrast, continuous flooding of longer duration, particularly when applied early in the winter, increased recharge efficiency without increasing nitrate losses.

These findings show that recharge design is a dominant management lever, and that poorly timed or intermittent Ag-MAR can exacerbate nitrate losses, whereas carefully designed early-season recharge can simultaneously enhance groundwater recharge, improve soil water storage, and reduce growing-season irrigation demand without yield penalties.

Multi-year simulations further demonstrated that Ag-MAR alone, while beneficial for water storage, can lead to gradual declines in soil organic carbon (SOC). However, co-designing Ag-MAR with regenerative soil health practices, specifically compost amendments and winter cover crops, resulted in net SOC sequestration while maintaining low nitrate leaching. This highlights the importance of integrating soil physical management with biogeochemical controls to sustain soil resiliency under repeated recharge cycles.

By explicitly linking recharge practices to soil health metrics, nitrogen cycling, and crop water demand, this work addresses key W5188 priorities related to soil resiliency (2.1), soil health assessment (2.4), and challenges at the water–food–climate nexus (2.2). The results provide a quantitative basis for designing Ag-MAR systems that balance groundwater sustainability with long-term soil and water quality protection.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

No milestones for this objective.

Washington State University (Markus Flury and Joan Wu)

We developed new methods to quantify micro- and nanoplastics in rainwater and soil samples. We also developed isotope techniques to track the fate of polymer carbon from biodegradable plastic mulch films during biodegradation from the plastic films into soil organic matter, carbon dioxide, and microbial biomass.

Oregon State University (Salini Sasidharan)

1. To improve applied science and address soil-related challenges within the water-food-energy-climate nexus (i-j) we installed the rainwater harvesting system.

2. To expand soil moisture networks and their application (k), we will install the DeepVadoSense system and a drywell for practical applications (canal recharge in Herminston, Oregon, USA).

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

1. We improved the computational efficiency of parallelized python code to generate hydraulic estimates with PTFs on massive data sets, such as for the contiguous USA (760 million points, SOLUS and SoilGridsPlus). This code is now also works for an international dataset: OpenLandMap that has a resolution of 120 meter and 30 meter (few modifications were needed). While computationally feasible with even modest means, the storage requirements and challenges to distribution of the products are formidable : the 10-20 billion points in the global dataset would require 40-50 terabytes. We have a proof-of-concept solution that reduced the storage requirements to about 1% (so: gigabytes instead of terabytes) without loss of precision. We are now working on turning this into a (for others) usable product that can easily be distributed. The ultimate product would provide a full 5 to 7-parameter estimate of soil hydraulic properties and their covariance for nearly all land locations in the world at a resolution of 120 and 30 meters.

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

1. Applied findings to optimize plant growth media for space applications, focusing on porous media that support consistent water and nutrient delivery.

University of Nebraska (Aaron Daigh)

1. Calibrated and validated a vadose zone model and completion of virtual experiments to understand the effects of long-term fertilizer application rates, crop rotations, and weather impacts on aquifer nitrate contamination.
2. Calibrated and validates a vadose zone model for leaching under livestock carcass composting piles and completed geographic risk maps across Nebraska.

Oklahoma State University (Tyson Ochnser)

- Improve Oklahoma Automated Soil Information System (OASIS) and evaluate potential for nationwide expansion.
    - ongoing, code base has been converted to Python 3, added ingest capabilities for data from new sensors, working on statewide soil texture maps for the depths of the new sensors
- Proof-of-concept decadal simulations of soil moisture dynamics as NRCS-SCAN locations.
    - completed, multi-decade simulations with SOILWAT2, TOPOFIRE, and SPORT-LIS

- Complete simulations of soil moisture dynamics at in situ monitoring stations nationwide using SOILWAT2 and TOPOFIRE.
    - completed, analysis of the simulation results are ongoing

University of Kentucky (Ole Wendroth)

1. Knowledge will be derived from model simulations over the next year how farmers' decisions can be improved to optimize the application rate of nitrogen fertilizer and irrigation water in different zones of the field.
2. Knowledge will be derived on how UAV-based flights over a given area can be accelerated by increasing the altitude and losing precision in the spatial resolution. How can early-season land surface images of soil and crops be used for nutrient and water management?
3. An answer will be derived if and how spectroscopic measurements can rapidly deliver a soil nitrate concentration profile over at least the upper 60 cm of soil.

North Carolina State University (Josh Heitman)

1. Soil thermal conductivity (λ) relates directly to heat conduction in soil. Numerous models have been developed to estimate soil thermal conductivity, but their applicability is often limited to specific types of soils. Recognizing the similarity between the soil water retention curve and the λ versus water content (θ) curve, Lu and Dong presented a λ(θ) model, which can provide accurate λ estimates for various soils but does not converge to the thermal conductivity value of a saturated soil (λsat) at saturation. We developed a modified form of the Lu and Dong (MLD) model. We also developed a neural network (NN) approach to estimate parameters of the MLD model using soil porosity, sand, silt, and clay contents, as well as the thermal conductivity of soil solids (λs) as input features. The NN-MLD model was tested with an independent testing dataset and compared with five pre-existing models taken from the literature. Results show that the NN-MLD model outperforms the other models across four error metrics. In addition, error analysis across varying degrees of saturation reveals that the NN-MLD model consistently outperforms the other models across the entire range of saturation levels and its superiority is most pronounced at medium levels of saturation, where the other models yield NRMSEs and MAEs values three times larger than those of the NN-MLD model.

1. Soil compaction leads to an increase in bulk density (ρ) and results in a shift in pore-size distribution toward smaller pores. These changes alter the soil hydraulic properties (SHPs): the water retention curve and the hydraulic conductivity curve. Most existing models that address the impact of changes in ρ on SHP have been confined to SHP models that consider only capillary water, neglecting water stored and transmitted within

adsorbed films (noncapillary water). Recently, a new prediction model was developed that combines the Peters–Durner–Iden (PDI) SHP model system, which accounts for capillary and noncapillary water, with a prediction scheme for compaction effects. We calibrated and tested this new approach against literature data from soils with varying textures. Two different variants, which vary in the number of degrees of freedom were tested. Remarkably, the variant with only one adjustable parameter, the one that shifts the pore-size distribution by scaling the pressure head, was sufficient to accurately describe the data. All other parameters can either be fixed at the reference value or scaled based on straightforward physical reasoning. The model achieved low calibration errors and performed satisfactorily in validation. Based on our results, we hypothesize that the scaling approach is independent of the capillary saturation function and that this method might be applied to other models within the PDI system without new calibration.

North Dakota State University (Kang Liang)

1. Assessed the impacts of bioenergy crops, tile drainage, and tillage on water quality.
2. Identified management tradeoffs affecting nitrogen losses in the Upper Mississippi River Basin and hypoxia in Gulf of Mexico.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

1. A thermo-time domain reflectometry (thermo-TDR) sensor combines a heat pulse sensor with a TDR waveguide to simultaneously measure coupled processes of water, heat, and solute transfer. The sensor can provide repeated in-situ measurements of several soil state properties (temperature, soil water content, and ice content), thermal properties (thermal diffusivity, thermal conductivity, heat capacity), and electromagnetic properties (dielectric constant and bulk electrical conductivity) with minimal soil disturbance. Combined with physical or empirical models, structural indicators, such as bulk density and air-filled porosity, can be derived from measured soil thermal and electrical properties. Successful applications are available to determine fine-scale heat, water, and vapor fluxes with thermo-TDR sensors. Applications of thermo-TDR sensors in complicated scenarios, such as heterogeneous root zones and saline environments, are also possible. Therefore, the multi-functional uses of thermo-TDR sensors are invaluable for in-situ observations of several soil physical properties and processes in critical zone soils.

2. Interpreting soil relative permittivity variations along a time domain reflectometry (TDR) waveguide provides an opportunity to determine soil water content at multiple depths using a vertically installed TDR sensor. Compared to placing sensors at different depths, vertical sensor installation reduces measurement efforts and enhances data-use-efficiency.

Revealing variations includes two aspects: identifying change positions and determining values. Traditional inverse analyses are not widely applied due to their high computational demands. Machine learning-based methods, e.g., TDR-CNN, provide a forward computational workflow to track change positions and reduce computational load, but errors in values are relatively large. In this study, TDR-Transformer is developed as a new waveform interpretation model to improve estimation accuracy. Modified from the standard transformer architecture, an encoder with convolutional neural layers is used to extract waveform geometric features, and a decoder generates a sequence of values to represent variations. Attention is a mechanism that can dynamically extract and process the relevant information within the data, which processes and integrates the waveform geometric information in the encoder, ensures the causality (time-order) of the waveform data in the decoder, and transfers information from the encoder to the decoder. TDR-Transformer was trained and tested using simulated waveforms where changes along the waveguides, but soil electrical conductivity (EC) was assumed to be small and stable. The RMSE for values was within 0.5-1.6% and the RMSE of change positions was within 5-8%. A soil infiltration experiment and a precipitation-evaporation experiment illustrated applications of TDR-Transformer to observed waveforms. Consequently, TDR-Transformer is a promising artificial intelligence model to interpret TDR waveforms in soils with nonuniform , and fine-tuning TDR-Transformer is recommended for specific commercial TDR sensor designs.

3. Cereal rye (*Secale cereale* L.) has been extensively studied as a winter cover crop in conservation agriculture using experimental and modeling approaches. Previous studies generally modeled cereal rye by modifying existing cash crop models. We develop and evaluate a new cereal rye vegetative growth model. The new model, namely RYESIM, employs object-oriented programming techniques and a linked-list data structure to present the emergence order of cereal rye organs, such as leaves, internodes, and tillers. Individual organs are abstracted as “classes,” which encapsulate organs’ morphological features and emergence-growth-senescence processes as member variables and functions. Multiple organs are assembled based on the tiller hierarchy to formulate the cereal rye plant architecture. RYESIM also contains “representative plant” as an average process among multiple individual plants, which bridges individual organs’ growth and field-scale averaged plant morphology, as well as ensuring plant-level biomass and nitrogen (N) mass balance. Existing soil (2DSOIL) and biochemical photosynthesis models are incorporated to estimate soil water-nutrient supply, carbon assimilation and transpiration. RYESIM was evaluated using published field data measured in the Mid-Atlantic region of the USA. Compared to observed values, the relative mean absolute errors of RYESIM for tiller number, aboveground biomass and N mass were within 0.3, 0.4 and 0.5 (with exceptions), and the RYESIM simulated values fell within the value ranges from literature results. Therefore, RYESIM provides effective simulations on cereal rye

vegetative growth, and the RYESIM model structure also provides a paradigm for future "multi-tiller" cash crop model development.

4. Microbial detection techniques, such as bacterial counting, are essential in all aspects of environmental monitoring and analysis. However, the standard plate count method for bacterial enumeration with colony-forming units is time-consuming and labor-intensive. In this study, we present a fast and accurate method to count bacteria cells using the technique of time-domain reflectometry (TDR) based on the electrical properties of bacterial cell suspensions. A series of suspensions with various bacterial concentrations were used as the test materials, and the electrical conductivity (σa) was determined using the TDR method. The TDR measured-σa value was converted to the concentration of bacterial suspension using a pre-established standard curve on three types of bacteria, i.e., Bacillus subtilis (B. subtilis), Pseudomonas fluorescens (P. fluorescens), and Escherichia coli (E. coli). The σa values of suspensions increased exponentially with bacteria concentrations, mainly due to the release of Cl^- and extracellular polymeric substances from the cells that were electrically conductive. For the three types of bacterial strains, the lower detection limits were 6 log CFU mL^{-1} for B. subtilis, and 7 log CFU mL^{-1} for P. fluorescens and E. coli. Independent evaluation showed that values from the TDR based method matched well with those obtained with the traditional plate count method, with RMSEs of 0.260, 0.166, and 0.198 log CFU mL^{-1} for B. subtilis, P. fluorescens, and E. coli, respectively. The TDR based approach provides a fast and accurate means for detecting bacterial cell numbers in suspension.

5. Plastic liners are sometimes used with soil samplers in order to collect and store intact soil cores. Gaps at the soil–wall interface caused by the flexibility of plastic liners can result in wall flow, preventing accurate fluid flux density measurements. A subsampling method was developed to overcome problems with wall flow from soil samples collected with plastic liners in order to measure air permeability (ka) and saturated hydraulic conductivity (Ksat) on the intact cores. Subsamples were obtained after first immobilizing the soil within plastic liners by injecting expanding foam into the gaps between the soil and the liners. Once the soil was fixed in place, the soil samples were cut to the desired length, and sharpened metal rings were inserted into the original soil sample with a vise. With the metal ring at the desired depth, the subsample was removed from the original soil sample by cutting the liner and removing excess soil from the ends of the rings. Initial attempts to measure ka and Ksat on samples within the original liners led to unrealistically high values because significant wall flow occurred. However, after implementing the improved subsampling approach, the measured ka and Ksat of the subsamples were within the range of expected values based on the literature. The subsampling method effectively eliminated wall flow on soil originally collected in plastic liners and is relatively easy to implement without the need for specialized tools.

6. Traditional rhizoboxes have long been utilized in plant and soil science research to study root development and soil interactions. Building upon this foundational tool, we have developed the Smart Rhizobox System, an innovative advancement that integrates modern technology to enable real-time monitoring of root growth and soil water movement, particularly under varying soil compaction conditions. This system combines a development board with custom embedded software to manage data acquisition from multiple sensors, including eight soil moisture sensors, a temperature sensor, and a pH sensor, allowing continuous tracking of soil conditions. A GoPro camera-based imaging system captures high-resolution images of soil and plant roots throughout the growing period, which are then processed using a PC application equipped with AI-driven computer vision algorithms. Unlike hyperspectral imaging systems, which capture data across multiple narrow spectral bands to analyze plant stress, water content, and nutrient levels, GoPro cameras operate in the visible light spectrum using standard RGB imaging. While GoPro does not provide hyperspectral data, it offers a cost-effective and high-resolution solution for tracking root morphology, depth, and growth dynamics in real-time. The Smart Rhizobox PC application enhances analysis by automatically identifying and tracking root structures, distinguishing roots from soil using calibrated algorithms. The system allows for simultaneous monitoring of multiple rhizoboxes or multiple plants within a single rhizobox, generating quantitative data on root depth, total root area, and root diameter. Additionally, the system maintains a comprehensive database, offering interactive graphs and search functions for easy data access. By integrating real-time imaging with automated analysis, the Smart Rhizobox System provides an advanced platform to study root-soil interactions, water infiltration, and plant adaptation mechanisms under different soil types, and compaction scenarios. As a first-of-its-kind development, this system represents a significant advancement in soil physics research, delivering high-resolution spatial and temporal data that contribute to improved soil management strategies and precision agriculture practices. Furthermore, we have developed a user manual to support both research and education, ensuring that researchers, educators, and students can effectively utilize this system for studying soil-root interactions, environmental conditions, and plant responses in controlled experiments.

Virginia Tech (Ryan Stewart)

1. To build and test a new system for using repeated handheld LiDAR scan to monitor soil particle movement during erosion, by May 2026.
2. To publish a theoretical framework to interpret soil hydraulic properties from single ring infiltration measurements, by August 2026.

University of Delaware (Yan Jin)

- Completed the deployment and operation of a long-term coastal field monitoring framework, generating continuous datasets of soil redox potential, porewater chemistry, and hydrological variables, and developed data processing pipelines for time-series integration and quality control.
- Developed the EEI framework to quantify evaporative enrichment in isotopic mixing models.
- Tested isotope-only and isotope + salinity EMMA approaches and compared model performance.

University of Wisconsin-Madison (Jingyi Huang)

- Models and a Python package were developed for predicting surface and rootzone soil moisture dynamics across the cropland in the continental USA
- Sensors developed for monitoring soil water and nitrate contents in soils

Michigan State University (Jiquan Chen)

No milestones for this objective.

Michigan State University (Wei Zhang)

No milestones for this objective.

University of Florida (Ebrahim Babaeian)

1. Characterized the physical and hydraulic properties of twenty commercially available domestic soilless substrates to evaluate their suitability as agricultural growth media.
2. Developed a scalable deep learning framework to estimate daily subsurface soil moisture by integrating SMAP satellite ancillary data with NRCS SOLUS100 soil physical property maps at regional to large spatial scales.

Connecticut Agricultural Experiment Station (Yingxue Yu)

We conducted an experimental study to quantify how tire wear particles (TWPs), a dominant and chemically distinct source of microplastic contamination in terrestrial environments, influence soil physical properties that regulate water availability. A loamy sand soil was amended with cryogenically ground TWPs (mean size ~45 µm) at environmentally relevant concentrations (0–1% w/w) and packed under controlled conditions. Soil water retention was characterized over a

wide range of matric potentials using HYPROP (near saturation to ~10^3 hPa) and WP4C (to ~10^6 hPa), enabling derivation of key agronomic indicators including bulk density, field capacity (−330 hPa), permanent wilting point (−15,000 hPa), and plant-available water. TWP incorporation increased bulk density, consistent with pore filling and altered packing, while field capacity and water holding capacity showed variable but overall declining trends with increasing TWP content. Permanent wilting point decreased with TWP addition, indicating reduced water retention at low water potentials, likely related to the hydrophobic nature of TWPs. These findings demonstrate that TWP contamination can measurably alter soil physical behavior and soil–water relationships, with potential consequences for soil health, irrigation efficiency, and plant water availability.
We authored a comprehensive review examining the vadose zone as a critical, variably saturated interface that underpins essential ecosystem services, including food and water provisioning, climate regulation, and infrastructure stability. The review synthesizes current understanding of vadose zone processes under increasing pressures from climate change and other anthropogenic and natural stressors, highlighting the need for integrative and cross-disciplinary approaches. We identify key knowledge gaps and research opportunities across six thematic areas: scaling and modeling of vadose zone properties and processes, soil moisture monitoring and observation networks, surface energy balance dynamics, interactions between preferential flow and biogeochemical processes, fire–vadose zone feedbacks, and the fate and transport of emerging contaminants. By consolidating recent advances alongside unresolved challenges, this review provides a forward-looking framework to guide future vadose zone research and support the sustainable management of soil and water resources.

Texas A&M University (Briana Wyatt)

No milestones for this objective.

Texas A&M University (Binayak P. Mohanty)

1. Developed a dual-index framework for assessing irrigation practices across productivity and climate impact dimensions.
2. We quantified key thresholds for classifying SOC gain potential by switching from conventional tillage to long-term no-tillage with residue retention.
3. Coupled soil moisture and ET regime characteristics were discovered across various land use land covers and hydroclimates across the globe.
4. Ecosystem respiration, soil health, and GHG emission estimations were improved by accounting soil moisture, temperature, and land surface radiation dynamics.

University of Hawaiʻi at Mānoa (Jing Yan)

1. Collected and characterized representative soils by obtaining samples from agricultural fields in Oʻahu, Hawaiʻi (primarily Oxisols) and completing laboratory analyses of their physical, chemical, and hydraulic properties.
2. Established a controlled microbial experimentation framework by developing and validating procedures for soil sterilization and microbial inoculation to support mechanistic studies.
3. Assessed microbial impacts on soil hydraulic behavior through preliminary experiments that quantified microbial responses, morphological changes, and resulting modifications to soil hydraulic functions.

University of Tennessee-Knoxville (Xi Zhang)

No milestones for this objective.

Montana State University (Jack Brookshire)

No milestones for this objective.

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

4. Detailed soil maps are needed to support precision irrigation and salinity management in specialty crops. Several promising sensor technologies exist for mapping soil properties such as water content, salinity, and texture, but their use in specialty crop fields is hindered by the non-uniform soil wetting that occurs under drip and micro-sprinkler irrigation. ARS researchers at Riverside, California, and collaborators from the University of California developed a mobile sensor platform and data post-processing and fusion algorithm for on-the-go soil characterization of micro-irrigated orchards. The system has shown promise by generating detailed soil maps that may enhance irrigation management for citrus and other specialty crops.

Objective 3: Integrate scale-appropriate methods to improve decisions of soil and water resources

University of California, Riverside (Hoori Ajami)

1. Develop computationally efficient modeling frameworks for fluid flow and transport at watershed scale
2. Improve parameterization of crops in integrated groundwater-land surface models

3. Integrate groundwater age data to improve recharge estimation in mountain catchments

University of California, Riverside (Jirka Šimůnek)

Agricultural Applications:

1. Chen et al. (2025) evaluated soil salt dynamics in a tomato-corn intercropping system with different spatial arrangements using field experiments and numerical modeling using HYDRUS-2D.
2. Naderi et al. (2025) provided a comparative assessment of methods for estimating the gray water footprint under paddy field conditions.
3. Liu et al. (2025a) generated high-precision maps of farmland irrigation patterns using remotely sensed ecological indices and machine learning algorithms.
4. Liu et al. (2025b) integrated data assimilation, crop modeling, and a multi-objective optimization framework to improve cotton irrigation water-use efficiency.

University of California, Davis (Thomas Harter)

- Developed initial version of a salt feedback loop in our nonpoint-source assessment tool to simulate groundwater salinization in the Central Valley
- Continued collaboration with CV-SALTS to develop groundwater salinity transport model for the irrigated agricultural landscape of the Central Valley.

University of California, Davis (Majdi Abou Najm)

- Developed and established an agrivoltaics research facility enabling investigation of coupled soil–water–energy–plant interactions relevant for land and resource management.
- Conducted field experiments quantifying crop yield and water use efficiency responses under altered radiation regimes.
- Generated experimental evidence informing management considerations for dual-use agricultural and energy systems.
- Contributed modeling studies addressing nitrate leaching risks associated with managed aquifer recharge practices.

University of California, Davis (Helen E. Dahlke)

This research contributed substantially to the development and application of process-based modeling frameworks for characterizing soil and vadose zone processes under conditions of strong heterogeneity and non-equilibrium flow.

A key methodological contribution was the development of a dual-porosity reactive nitrogen transport model using HYDRUS-1D, incorporating a three-species nitrogen reaction chain (organic N → NH_4^+-N → NO_3^--N). The model was calibrated using field-measured pore-water and extractable soil nitrate data and successfully reproduced observed concentration dynamics across multiple depths.

Global sensitivity and uncertainty analyses were applied to identify dominant transport and reaction parameters, revealing how parameter importance shifts with soil texture, legacy nitrate storage, and preferential flow strength. This work demonstrates the value of combining model–data fusion with uncertainty analysis to identify controlling processes and improve confidence in predictions of nitrate fate under recharge scenarios.

In parallel, DSSAT cropping system models were parameterized and applied to simulate soil water and nitrogen dynamics across single-event and multi-year time scales, bridging root-zone processes with deeper vadose zone behavior. Together, the DSSAT and HYDRUS frameworks provide complementary tools for evaluating Ag-MAR impacts from the root zone to the deep vadose zone and groundwater.

By advancing process-based model development and parameterization (3.4) and demonstrating the value of integrated modeling approaches across scales, this work contributes directly to W5188 methodological objectives and provides transferable modeling strategies for other managed recharge and nutrient management applications.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

No milestones for this objective.

Washington State University (Markus Flury and Joan Wu)

We investigated how plant take up micro- and nanoplastics in different growth media: agar, hydroponics, and soil. Three different nanospheres were used (40 nm and 200 nm carboxylate-modified and 200 nm amino-modified polystyrene) and uniformly mixed into the growth media. Plants were grown for 7 to 10 days and the roots were then examined for the presence of nanospheres by confocal laser scanning microscopy and scanning electron microscopy. We observed the 40 nm nanospheres inside the plant roots, but the 200 nm nanospheres only adhered to the root cap cells showing no uptake into the roots. Furthermore, confocal images indicated that root uptake of nanospheres was favored in hydroponic solutions as compared to agar and soil media. Plant biomass was generally not affected by the nanospheres, except for hydroponically grown Arabidopsis thaliana, where biomass was significantly reduced. We provide evidence that polystyrene nanospheres can be taken up into the interior of plant roots and cause plant stress, but these impacts are less pronounced in media where the plastic particles are less mobile, like in agar and soil media as compared to hydroponic systems.

We adapted a simple, hydrologic Sensitivity Index method, for optimal placement of rain gardens to combat urban stormwater runoff and associated adverse environmental impacts. The method uses publicly accessible geospatial data about soil, topography, and surface imperviousness, and is readily implemented in a Geographic Information System (GIS). We corroborated the adequacy of the indexing approach through process-based hydrologic assessment and ground truthing.

Oregon State University (Salini Sasidharan)

To apply geophysical tools to better quantify subsurface heterogeneity, hydrologically relevant properties, and groundwater and vadose zone interactions (m) : Large scale geophysical survey with towed-Transient Electromagnetic and walk-Transient Electromagnet at the Lower Umatilla basin methods were conducted in January 2025. Subsurface characterization of proposed DeepVadoSense site with Electrical Resistivity Tomography was conducted in last quarter.

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

1. We generated soil hydraulic property maps of five van-Genuchten parameters (theta_r, theta_s, alpha, n, and Ks) for the contiguous USA at 100 meter resolution and seven depths (surface to 2.5 meters) for the SOLUS100 NRCS data product. Similar to our previous work, data and code will be made available in open formats with results validated for accuracy with NCSS Soil Pedon data.
2. We conducted Hydrus1D simulations for selected locations in an agricultural region in China with severe groundwater over-use (the Ningbailong depression zone). The simulations used estimates of hydraulic properties for deep (50 meter) profile and evaluated rain-fed infiltration and flood/river -fed infiltration. One of the conclusions is that infiltration basins that accept local flood waters may significantly reduce the effects of groundwater over extraction and assure long-term water sustainability. The project findings may be relevant to locations in the USA.

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

1. Advanced EM sensor performance characterization using several approaches described in published papers.
2. Published Physics-Informed Deep Learning approach for soil moisture forecasting.

3. Submitted paper describing design and testing of PCB-based antenna probes for accurate near-surface soil moisture measurement.

University of Nebraska (Aaron Daigh)

No milestones for this objective.

Oklahoma State University (Tyson Ochnser)

- Quantify inter- and intra-sensor variability using in situ soil moisture sensor testbeds
    - completed, manuscript submitted

University of Kentucky (Ole Wendroth)

1. For the application of SWAT+, is the delineation of a farmer's field into hydrologic response units (HRUs) feasible to derive site-specific management decisions? Is alternatively a 1-dimensional simulation model dividing a farmer's field into a raster of 1-D vertical profiles more effective in terms of model input and integration of information across the field?
2. What is the loss of information from UAV- or satellite-based images derived from higher altitudes that are obtained at coarser resolution than images from UAV-based low altitude (150 m) flights. Are visual and spectral reflections typic for certain terrain attributes that would allow a DEM-based upscaling of land surface observations?
3. What area does a single spectroscopic measurement of soil nitrate concentration reflect or how many spectral scans are necessary to represent the spatial variability pattern of nitrate over a given area in a farmer's field?

North Carolina State University (Josh Heitman)

1. In the Northern Great Plains, the period between small grain harvest and the first killing frost leaves soil vulnerable to erosion, particularly if crop residue is removed or reduced by tillage. Integrating cover crops can reduce erosion risk and improve soil health, but in water-limited areas, overwintering cover crops may lower soil water content and delay spring germination. Our work evaluated how crop residues and cover crops influence soil temperature and water content. Three treatments were tested after barley (Hordeum vulgare L.): (1) bare soil, (2) barley residue, and (3) cereal rye (Secale cereale L.) and flax (Linum usitatissimum L.) cover crops no-till drilled into barley residue. Soil temperature, water content, net radiation (Rn), and soil heat flux (G) were measured from mid April to May. Surface cover significantly affected Rn, G, and temperature compared to bare soil. Bare soil had the greatest cumulative Rn and G, which increased soil

temperatures at the 3-cm depth compared to barley residue and cover crops. Although bare soil had higher mean temperatures, it had the lowest minimum temperature during cooling periods. Despite expectations that cover crops would reduce soil water, no significant differences were observed.

North Dakota State University (Kang Liang)

1. Advanced modeling estimation of nitrate load using sparse measurement.
2. Improved SWAT calibration and uncertainty analysis for tile-drained systems.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

1. Gully erosion degrades our critical soil resource. Machine learning models have proven effective in mapping soil erosion susceptibility, at least for selected terrains. However, in areas with different terrain complexity, these models show significant differences in identifying in optimal spatial resolution and algorithms. Gully erosion susceptibility mapping in two small watersheds: one located in the complex terrain of the Loess Plateau and the other in the relatively flat terrain of the Northeast China Mollisol region, was used to test for differences in optimum resolution for model inputs. This study, conducted by Annan Yang, Chunmei Wang, Qinke Yang, Guowei Pang, Yongqing Long, Lei Wang, and Richard M. Cruse, indicates: 1) significant differences in optimal resolution of gully erosion susceptibility mapping exists in the two regions, 1–2.5 m for the Mollisol region, and 2.5–5 m for the Loess Plateau. The extreme boosting tree (XGBoost) algorithm delivered the best simulation results vs. the random forest (RF) and gradient boosting decision tree (GBDT) in both regions. 2) Slope gradient and contributing area impacted gully distribution in both watersheds, while land use in the Loess Plateau and distance from streams in the Mollisol region were most important. 3) Twenty five percent of the Loess Plateau area was highly susceptible to gully erosion, while only 1% of the Mollisol watershed was highly susceptible.

2. Soil heat flux plates (SHFPs) are widely used to measure soil heat flux (Gs). Gs is often underestimated by SHFPs (Gp). Although calibration methods are used, they are not always effective. The objective of this study is to evaluate the effectiveness of a field calibration method applied to various SHFPs installed in a full canopy maize field. A 5-day measurement period with wet and dry soil conditions was used for calibration, while 80-day and 60-day measurement periods were used for evaluation. Uncorrected SHFP measured values (Gp) underestimated the actual reference Gs determined by the gradient method (Gs_grad) by 42%–64%. Gp values in the evaluation period were corrected (Gp_corr) by dividing them by the ratio of Gp/Gs_grad determined over the calibration period. After the correction, the Gp_corr agreed well with the Gs_grad, with

Gp_corr/Gs_grad of four of six SHFPs being 0.90–1.01, improving to 74%–98%. The field calibration performed approximately the same with the wet and dry calibration periods, whether the calibration and evaluation periods were consecutive in time or had relatively long time intervals, indicating that this method accounted for almost all errors with SHFP. This is largely due to the slight variation in soil thermal conductivity and the linearity between soil temperature gradients from SHFP and the gradient method under relatively stable soil moisture conditions. This study deepens our understanding and improves the accuracy of soil heat flux measurements. Calibration of SHFPs under various land covers and weather conditions is warranted in future studies.

3. Designing regionally resilient cropping systems requires understanding the interactions of multiple factors important to crop production and soil erosion-susceptibility both spatially and temporally. The objectives of this study were to elucidate the relationships between regional hillslope soil loss and Daily Erosion Project (DEP) tillage management scenarios and assess the sensitivity of hillslope soil loss to different field residue covers associated with these tillage scenarios. DEP simulations used the same tillage management scenario for the entire domain. Scenarios consisted of the six tillage categories within DEP (T1 to T6), with increasing values implying more intense tillage (less residue). Results indicated a direct relationship between tillage intensity (less residue cover) and higher erosion rates at different spatial scales (statewide, major land resource areas [MLRA], and DEP watersheds). The study also revealed a significant spatial variability across the DEP domain, identifying erosion-prone regions along the Missouri River and eastern Iowa and Minnesota, surpassing in many scenarios 17.9 Mg/ha/yr. Other areas showed no response associated with increasing tillage intensity, demonstrating how local factors such as topography, soil, land use, and climate and their interaction could also affect erosion. The sensitivity analysis uncovered a very high erosion sensitivity to small changes in residue cover, especially in hilly watersheds, while transitioning from no-till to tilled systems. Overall, this regional study underscores the importance of residue cover management and minimal soil disturbance in reducing hillslope erosion and illustrates the critical role landscape and management interactions play in spatially variable regional hill slope soil erosion rates.

Virginia Tech (Ryan Stewart)

1. To provide recommendations for vineyard soil management that enhances wine-grape quality and soil health, by December 2026.

University of Delaware (Yan Jin)

- Demonstrated how isotope-based metrics can improve the interpretation of coastal monitoring data.
- Compiled a global database of soil organic matter chemical composition and are currently integrating U.S. wide soil samples and associated physicochemical property datasets through collaboration with ERDC, thereby establishing a harmonized dataset suitable for comparative and meta-analytical studies.
- Developed and evaluated a methodology to obtain high resolution data of hydraulic properties of soils under wetting-drying cycles.

University of Wisconsin-Madison (Jingyi Huang)

- We organized a series of outreach events on 2025 Ag Discovery Day at Wisconsin State Fair Park and Wisconsin Science Festival (Science on the Square) to improve the diversity, equity, and inclusion of underrepresented groups particularly K-12 students in STEM disciplines

Michigan State University (Jiquan Chen)

No milestones for this objective.

Michigan State University (Wei Zhang)

No milestones for this objective.

University of Florida (Ebrahim Babaeian)

1. Developed an initial version of pedo-transfer functions using deep and convolutional neural networks that leverage multi-depth SOLUS100 soil property maps to estimate soil hydraulic properties to support agricultural water management and flood risk mapping in Florida.
2. Developed a hybrid soil moisture retrieval framework that integrates field-scale L-band microwave observations with physically based radiative transfer modeling and machine learning algorithms to estimate and map surface-to-root zone soil moisture at the field scale.

Connecticut Agricultural Experiment Station (Yingxue Yu)

No milestones for this objective.

Texas A&M University (Briana Wyatt)

1. Modeled the impacts of woody plant removal on groundwater recharge to the Carrizo-Wilcox aquifer to inform decision making regarding land use management in the region.

Texas A&M University (Binayak P. Mohanty)

1. An optimal transport soil moisture – evapotranspiration coupling framework was proposed using least action hypothesis.
2. Texas Water Observatory has been established in the Gulf coast region which facilitates various soil hydrologic, ecosystems, and land-atmosphere coupling studies.
3. Several new process-cum-data-driven models were developed including model for root zone soil moisture estimation, preferential flow to shallow ground water, scaled hydraulic properties, and characteristics soil health parameters.

University of Hawaiʻi at Mānoa (Jing Yan)

No milestones for this objective.

University of Tennessee-Knoxville (Xi Zhang)

1. Evaluated the water use by cover crops to quantify the impact of cover cropping on soil water storage, availability, and recharge in the fields.

Montana State University (Jack Brookshire)

No milestones for this objective.

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

No milestones for this objective.

Objective 4: Translate new concepts and methods to students, stakeholders, and the public
Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

Oregon State University (Salini Sasidharan)
To improve outreach, extension, and education Making our science more actionable for stakeholders and decision makers through knowledge translation, extension, and public outreach (n):

1. PI (Dr. Sasidharan) visited India and established MOU with IIT Madras, IIT Hydrabad for developing Sustainable Water Management project and collaborate long term;
2. Dr. Sasidharan conducted a 5 day workshop at Gaudium International School, Hydrabad, India to high school students, on Sustainable Water Resources Management to teach students about the most recent advances in data collection, sensors, modeling, in water resources management.
3. Also, stakeholder engagement at Openhouse Day at and Ag Tech day at NWREC.
4. Gave field tour to students part of the OSU's College Assistance Migrant Program (CAMP) and the College of Engineering.

Extra milestones (Social and legal requirements)

- Survey at the proposed DeepVadoSense site at the Lower Umatilla basin was conducted by a surveyor in last quarter.
- Proposed Vadose Sense site was approved by OSU estate and legal team in last quarter.
- ASR permitting for controlled recharge was approved by OWRD for North Willamette Research and Extension Center site.

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

1. Training: The project provided hands-on mentoring for two undergraduate students and one postdoctoral researcher in soil sensing, sensor calibration, experimental design, data analysis, and machine-learning applications, with continued professional engagement of former lab members through collaborative research.
2. Professional development: Trainees and collaborators participated in conferences, workshops, and seminars, enhancing technical expertise, communication skills, and professional networks in soil physics, environmental sensing, and data science.

Oklahoma State University (Tyson Ochnser)

- Version 10 of the "Rain or Shine" textbook released.

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

No milestones for this objective.

Impact Statement

University of California, Riverside (Hoori Ajami)

This research investigates surface and subsurface flow dynamics, with a specific emphasis on groundwater recharge within mountain-valley aquifer systems. By improving the parameterization of subsurface hydraulic properties and crop water use in numerical models, we have enhanced the accuracy of hydrological forecasting. Our findings have been disseminated to diverse stakeholders through national and international conferences, as well as local community meetings. Ultimately, this work provides a critical foundation for sustainable water resource management in California and beyond.

University of California, Riverside (Jirka Šimůnek)

The HYDRUS models are continually updated based on the basic research conducted by the W5188 group. The HYDRUS-1D model was downloaded more than 10,000 times in 2025, and over 60,000 HYDRUS users from all over the world registered on the HYDRUS website. We continue to support all these HYDRUS users from the USA and around the world on the HYDRUS website through various tools, such as Discussion forums and FAQ sections, and by continuously updating and expanding the library of HYDRUS projects.

Finally, in 2025, we offered four short courses on the use of HYDRUS models in Europe, North America, China, and the Middle East. Over 150 students participated in these short courses.

University of California, Davis (Thomas Harter)

- Our work has major impacts on nutrient management practices in irrigated agriculture.
- We have provided efficient and affordable new tools for assessing irrigation and nutrient management practices for their future impacts to groundwater, which is now being used by California to guide grower practices that better protect groundwater quality.
- Our exemplary and pioneering work in developing groundwater sustainability plans is shaping the future management of groundwater resources in basins with significant groundwater-surface water interactions.
- We are expanding our work with new USDA NIFA funding into other western states.
- We are the technical service provider for the California water rights division in the State Water Board to provide guidance on drought emergency curtailment orders.

University of California, Davis (Majdi Abou Najm)

Agrivoltaics touches on a wide range of broad public interest topics, from saving water to improving soil health, to generating energy while producing food, to agricultural resilience, to food and energy safeties. Our work is demystifying Agrivoltaics to farmers and proving more details and information on this dual-use technology. Many of the attendees of the agrivoltaics conference expressed how appreciative they were for learning about agrivoltaics and identifying resources and contacts in this area. The conference and the agrivoltaics research roundtable events were significant milestones in bringing major public awareness and visibility to agrivoltaics.

University of California, Davis (Helen E. Dahlke)

This research generated new, actionable knowledge at the intersection of soil physics, vadose zone hydrology, biogeochemistry, and groundwater management, with impacts that extend beyond Agricultural Managed Aquifer Recharge to broader soil and water sustainability challenges.

- The work demonstrated that non-equilibrium flow and preferential transport are dominant controls on nitrate fate during large water application events, advancing fundamental understanding of water and solute transport in heterogeneous vadose zone systems.
- Results showed that Ag-MAR design parameters—particularly timing and intermittency—are primary determinants of nitrate leaching risk, emphasizing that groundwater recharge outcomes depend as much on management decisions as on site characteristics.
- By quantifying how early, continuous winter Ag-MAR can enhance recharge efficiency without increasing nitrate losses, this research provides a science-based pathway for improving groundwater recharge while protecting water quality.
- The integration of regenerative soil health practices with Ag-MAR demonstrated that soil organic carbon sequestration and reduced nitrate leaching can be achieved simultaneously, highlighting opportunities to align groundwater sustainability with climate mitigation and soil resiliency goals.
- The development and application of dual-porosity reactive transport models improved the ability to assess groundwater vulnerability by explicitly accounting for preferential flow, mobile–immobile exchange, and nitrogen transformation processes that are often neglected in simpler modeling approaches.
- This work provides transferable modeling frameworks and decision-relevant insights that support the design of Ag-MAR best management practices across diverse soil textures and hydrogeologic settings.
- Through graduate training, peer-reviewed publications, and conference dissemination, the research contributed to capacity building within the soil physics and vadose zone

hydrology communities, supporting the W5188 mission of advancing interdisciplinary science and preparing the next generation of scientists.

Desert Research Institute (Markus Berli), University of Nevada, Las Vegas (Zach Perzan, Hannes Bauser)

DRI improved our understanding of the water dynamics of desert soils and their impact on desert hydrology, in particular with respect to soils of reduced wettability and structural stability. UNLV improved our understanding of unsaturated flow during managed aquifer recharge, of solute flushing from soils during floods, and of the impacts of biocrusts on evaporation from bare soils.

Washington State University (Markus Flury and Joan Wu)

Biosolids are rich in nutrients and organic matter, thus, biosolids can serve as fertilizer and improve soil health. However, biosolids also contain contaminants, such as microplastics, which can lead to soil pollution and deterioration of soil functions. Our findings show that long-term biosolids application improved soil chemical and physical properties, with organic matter increasing by up to 71%, bulk density decreasing by 22%, and field capacity increasing by 24%; however, biosolids application also led to a decrease of pH from 5.5 to 4.8. Enhanced pore connectivity revealed by X-ray computed tomography provides the microscale explanation for improved water retention. Soil Compaction was not impacted by biosolids applications. Benefits provided by biosolids outweighed the negative impacts due to the presence of microplastics.

Green Stormwater Infrastructure is built to intercept stormwater runoff and mitigate peak flows and stormwater pollutants. A rain garden is a small-scale GSI comprising a plant-soil system in which water retention and pollutant mitigation are maximized through infiltration and storage. Proper placement of rain gardens within the watershed is crucial to maximizing their effectiveness. The Hydrologic Sensitivity Index approach uses publicly accessible geospatial data and is readily implemented in a GSI environment. This approach provides a practical, scalable, and transferrable tool for prioritizing GSI placement at the landscape scale.

Oregon State University (Salini Sasidharan)

- Understanding subsurface properties and heterogeneity enables smarter, more sustainable groundwater management by helping to:
    - More accurately estimate available groundwater resources
    - Reduce the risk of over-extraction and depletion
    - Improve well and infrastructure planning by identifying optimal locations for new wells

  - Support evidence-based water policy that protects reliable aquifers and helps safeguard community water supplies
  - Improve drywell design by maximizing aquifer recharge, improving groundwater quality, and preventing clogging.
  - Installation of drywells can improve groundwater quality
- Grants, contract and other resources obtained by one or more project members as a results of project activities:
  - The OSU Promising Scholar Award was presented to the PI (Dr. Salini Sasidharan) in recognition of her impactful research, leadership in addressing groundwater contamination challenges, success in securing major research funding, and outstanding mentorship and teaching in water and biosystems engineering.
  - Transdisciplinary Research Seed Fund USA-India collaboration: Awarded to PI Sasidharan (USD 50,000) entitled Smart Groundwater Recharge: A Transdisciplinary USA-India Framework for Eco-Resilient
  - Groundwater Sustainability, Flood Mitigation, and Irrigation Security.
  - The Competitive Agricultural Research Foundation Grant (2025) was awarded to the PI (Dr. Sasidharan) and postdoctoral scholar (Dr. Aravinth Ekamparam) through the project "Optimizing Water Treatment and Soil Health in Agrivoltaic Systems for Sustainable Agriculture and Managed Aquifer Recharge in Oregon" (USD 15,000).
  - Travel awards were given to graduate students to present findings associated with this project: (i) SSSA Kirkham travel award (USD 2,500) and (ii) The Northwest Association of Environmental Professionals (NWAEP) DEI Student Scholarship (USD 800).

University of Arizona (Marcel Schaap, Craig Rasmussen, and Karletta Chief)

- A challenge facing the practitioners in the fields of crop production, environmental engineering, as well as climate, drought, and ecosystem service assessments is the availability of soil hydraulic properties (in the form of soil water retention and hydraulic conductivity) at high-resolution with respect to position and depth. Unfortunately, it is usually cost-prohibitive to use laboratory or field methods to measure such data for more than a few locations, let alone for a country as large as the USA. Previously we published a proof of concept work (Schaap et al Vadose Zone Journal 2024). Presently we are working on a) improving hydraulic maps based on the recent NRCS SOLUS map, b) reducing data storage requirements of these maps (terabytes to gigabytes) c) quantifying effects of soil carbon dynamics on soil hydraulic properties in the context of drought and flood risk d) verification of simulated long-term drought dynamics for approximately 1000 points in the contiguous USA (based on mapped hydraulic properties.

- In addition to support received by W5188 a substantial amount of work is supported by: "Extending the NCSS SOLUS Product with Probabilistic Grids of Static and Dynamic Soil Moisture Data", USDA-NRCS Award NR233A750023C022

Utah State University (Scott B. Jones, Asghar Ghorbani, David A. Robinson (adjunct), and Morteza Sadeghi (adjunct)

New Grants:

- NASA– $1,878,190, MARS Office Contract #80NSSC23K0755, Sep 2025-Mar 2027, PI-Scott B. Jones-PI w/Bruce Bugbee and Curtis Bingham. The Utah Reusable Root Module For Food Production In Microgravity: Phase C
- Utah Ag Exp Station Seed Grant – $76,135, May 2025-Dec 2026, PI-Scott B. Jones w/ Juando Gonzalez-Teruel, Wenyi Sheng and Asghar Ghorbani, Novel Soil Surface Moisture Sensors and Machine Learning Connect Remote Sensing to Deeper Soil Moisture

University of Nebraska (Aaron Daigh)

1. Space Agriculture: A Comprehensive Systems-Level Review (Fazayeli et al.) A four-person crew traveling to Mars would require over 24,000 pounds of food for the journey, making in-space crop production a critical necessity for long-duration missions. Our comprehensive review identifies the interdependent challenges facing space agriculture on the Moon and Mars, which includes limited solar radiation, cosmic radiation 100–1000 times Earth levels, microgravity environments, regolith substrates with minimal nutrient-holding capacity, and the need for closed-loop systems. By synthesizing knowledge across environmental, biological, and engineering domains, this work provides a roadmap for developing integrated crop production systems. These insights advance both space exploration and controlled-environment agriculture innovations applicable to resource-limited settings on Earth.

2. Comparative Analysis of Four Soil Water Sensors (Maisha et al.) Effective irrigation management hinges on accurate soil moisture monitoring, yet sensor selection remains challenging for farmers and technical advisors. Our study evaluated four commercially available soil water sensors under field conditions in the Northern Great Plains, comparing their accuracy and reliability across diverse soil types and depths. Results identified significant performance differences among sensor technologies, providing practical guidance for selecting appropriate sensors based on soil conditions and management objectives. This research empowers farmers and agricultural consultants to make informed decisions about soil water monitoring, ultimately improving irrigation efficiency and water conservation in an era of increasing water scarcity.

3. Soil Management Legacy Provides Resiliency to Salinization (Daigh et al.) Soil salinization threatens agricultural productivity worldwide, yet the long-term protective effects of management practices remain poorly understood. Our case study reveals that historical soil management practices create a legacy effect that enhances soil resiliency against salinization pressures, providing critical insights into the processes and indicators that govern this protective capacity. These findings demonstrate that proactive soil management can build lasting defenses against salt accumulation, offering farmers a foundation for sustainable production in salt-prone regions.

4. Comparative Study of Croplands and Reference Sites for Soil Health Gap (Gamage et al.) Assessing soil health remains challenging due to variability in soil types, management practices, and climatic conditions, limiting our ability to set realistic improvement targets. Our study compared soil health indicators between croplands and undisturbed reference sites across diverse edaphic and climatic conditions in Nebraska, revealing that sites employing no-till and manuring practices showed 28% less organic matter depletion compared to 31–54% depletion under conventional tillage. This research validates the "Soil Health Gap" concept as a practical framework for establishing site-specific benchmarks and attainable targets for soil improvement.

5. Soil Health System Impacts on Dynamic Soil Hydraulic Functions (Tangen et al.) Climate change is intensifying growing season rainfall, yet how soil health management systems respond to intense precipitation events remains unclear. Our research quantified hydraulic functions in soil health systems before and after rainfall, demonstrating that on-farm soil health practices resulted in greater aggregate stability and improved pore networks compared to conventional systems. These findings confirm that combining soil health practices (living roots, persistent cover, diverse rotations, and minimal tillage) creates synergistic benefits for water infiltration and retention that persist even under intense rainfall. This knowledge equips farmers with evidence-based strategies for building climate-resilient soils that can better capture and store precipitation in an increasingly variable climate.

6. Emerging Issues and Research Opportunities in Vadose Zone Processes (Stewart et al.) The vadose zone faces mounting pressures from anthropogenic and climatic factors. Our review identifies key knowledge gaps and research opportunities across six thematic areas: scaling and modeling, soil moisture monitoring, surface energy balance, preferential flow paths, fire interactions, and emerging contaminants. By synthesizing recent innovations and compiling emerging challenges across disciplines, this work charts a path toward more comprehensive understanding of vadose zone processes.

7. Arbuscular Mycorrhizal Fungi for Zinc Biofortification in Lettuce (Kailer et al.) Zinc deficiency is a significant global public health concern linked to impaired immune function and pregnancy complications. Our research demonstrates that arbuscular mycorrhizal fungi (AMF) inoculation not only mitigates zinc toxicity in lettuce at high fertilization rates but also enhances zinc uptake and plant growth, enabling effective agronomic biofortification. Inoculated plants exhibited superior growth and zinc absorption capabilities, overcoming the yield reductions that typically limit biofortification efforts. This work establishes AMF inoculation as a practical tool for enhancing the nutritional value of vegetables while maintaining marketable yields, advancing sustainable strategies to address micronutrient deficiencies.

8. Large-Scale Slope Failures in North Dakota (Shafer et al.) Landslides in North Dakota, though often underestimated, cause significant economic and infrastructure damage across the state. Our analysis of over 66,000 mapped landslides identified 2,014 large-scale failures exceeding 100,000 m^2, revealing that these events preferentially occur on gentle slopes (mean 7.9°) within specific geological formations including the Sentinel Butte and Pierre Formations. Statistical analysis demonstrated that areas indicative of rainfall-induced leaching of pore fluid salinity correlates with slope instability, pointing to geochemical mechanisms underlying failure. These findings enable more accurate risk assessments and inform land-use planning to protect communities and infrastructure in vulnerable landscapes.

9. Value and Broader Impacts of Agricultural and Environmental Scientific Meetings (Daigh et al.) Scientific meetings are fundamental for advancing research through knowledge dissemination, networking, and collaboration, yet their socioeconomic value remains under quantified. Our analysis estimates the socioeconomic value of content presented at ASA-CSSA-SSSA Annual Meetings from 2014 to 2023 at $64.2 billion, highlighting the substantial scale of research dissemination at scientific conferences. Beyond quantifiable metrics, these gatherings provide transformative career benefits, fresh perspectives, and opportunities for public engagement that are difficult to measure but essential for scientific progress. This work underscores the critical importance of supporting scientific meetings as vital infrastructure for agricultural and environmental research advancement.

10. Nitrous Oxide Emissions from Irrigated Sugar Beet (Ghimire et al.) Nitrous oxide (N_2O) is a potent greenhouse gas, yet emissions from economically important crops like sugar beet remain understudied. Our two-year field experiment evaluated N_2O emissions across nitrogen fertilization rates, finding that cumulative emissions increased linearly with nitrogen application, with emissions 50% greater in wetter years. The fertilizer-induced emission factors were 0.71% (2022) and 1.32% (2023), averaging 1.02%, closely matched the IPCC default of 1%, validating its use for emission inventories the

understudied sugar beet crop. This research fills a critical data gap for greenhouse gas accounting in sugar beet production and provides guidance for nitrogen management strategies that balance productivity with environmental sustainability.

11. Field Calibration of TDR Sensor with Extension Pipe (Maisha et al.) Accurate soil water content measurement is essential for precision irrigation management. Our study developed field-specific calibration equations for a time-domain reflectometry sensor with extension pipe, improving measurement accuracy in soils with low coarse fragment content. Using gravimetric sampling as reference, the calibrated sensor achieved sufficient accuracy to serve as a benchmark for evaluating other commercial sensors in subsequent comparative studies. This work provides technical guidance for implementing sensor-based irrigation scheduling, supporting water conservation in agricultural regions where efficient water management is increasingly critical.

Oklahoma State University (Tyson Ochnser)

- This research includes ongoing scientific and career mentoring for five PhD students.
- This research engages soil scientists within NRCS to help adjust research outputs to stakeholder needs and interests.

University of Kentucky (Ole Wendroth)

- Past funding for this project came from commodity groups in Kentucky, i.e., Kentucky Small Grain Growers' Association, Kentucky Corn Growers' Association, Kentucky Soybean Board, and from Siemer Milling corporation.
- Financial benefits of optimized nitrogen and water management will result once the model simulations can successfully be conducted.

North Carolina State University (Josh Heitman)

Our work examines soil structure at a variety of spatial and temporal scales in order to better understand and manage important soil processes. These processes include water retention and infiltration, the exchange of gases, dynamics of soil organic matter and nutrients, root penetration, and the soil's vulnerability to erosion.

North Dakota State University (Kang Liang)

We advanced understanding of how various agricultural management practices affects hydrology, nitrogen transport, and downstream water quality. Our research results informed watershed management by identifying both the potential benefits and risks of different practices that intended to improve soil health and agricultural sustainability.

Iowa State University (Robert Horton, Elnaz Ebrahimi, Richard Cruse)

Our work examines soil structure at a variety of spatial and temporal scales, including controlled small-scale experiments, in order to better understand and manage important soil processes. These processes include water retention and infiltration, the exchange of gases, dynamics of soil organic matter and nutrients, root penetration, and the soil's vulnerability to erosion.

Virginia Tech (Ryan Stewart)

No impacts statement was provided.

University of Delaware (Yan Jin)

- Saltwater intrusion poses increasing challenges to coastal wetlands, yet conventional salinity-based indicators often fail to capture the underlying hydrologic and biogeochemical
- processes controlling ecosystem response. This project advances understanding by introducing a novel isotope-based metric (EEI) that improves the detection of evaporation, residence time, and
- mixing dynamics in tidal marsh porewaters.
- The results contribute to a more sensitive view of coastal monitoring data, supporting long-term management and resilience planning for wetland ecosystems under sea-level rise. By improving the mechanistic understanding of subsurface water movement and redox-sensitive processes, this work informs future research, monitoring strategies, and model development in coastal soil and water resources.
- Improved the understanding of microbial carbon utilization patterns and carbon sequestration from coastal forest to wetland.
- Enhanced scientific understanding of how sea-level rise and saltwater intrusion alter soil redox environments, nutrient release, and carbon emissions in vulnerable coastal wetlands, improving the basis for predicting ecosystem responses to climate-driven hydrological change.
- Provided empirical and data-driven support for coastal carbon conservation and management strategies by linking hydrological variability with soil biogeochemical processes across laboratory and field scales.
- Identified key predictors governing the global distribution of soil organic matter quality and clarified the relative importance of major global change drivers, strengthening the capacity to assess soil carbon stability under future environmental change scenarios.

- Improved understanding of the effects of salinity on soil KS through experiments utilizing wet-dry cycles, and 3 sequential saturation stages to mimic field behavior while maintaining close control of the experimental environment.
- The results of this KS study support the use of organic matter amendments, and/or farming techniques intended to increase soil organic matter, as a strategy to help preserve soil physical properties in cropland vulnerable to saltwater intrusion.
- Naseri, M. (2026). PLSC Graduate Student Travel Award ($855) for participation in the EGU26 General Assembly 2026, 3–8 May 2026, Vienna, Austria.

University of Wisconsin-Madison (Jingyi Huang)

- We have been awarded one USDA NIFA award to work on the spatial modeling of soil health properties using remote sensing and ground-based observations
- We have published 9 peer-reviewed papers and presented at various conferences and stakeholder meetings

Michigan State University (Jiquan Chen)

The AI4AgSys platform can be used by stakeholders to guide management decisions and explore alternative practices

Michigan State University (Wei Zhang)

Our project will help develop more effective agricultural practices to ensure food quality and safety. Our work will improve fundamental understanding on the movement of environmental contaminants such as PFAS and heavy metals in soil, water, and plant systems, which help better manage the risks from environmental pollution. The broader public could benefit from the greater availability of clean, safe, and healthy food and water supplies and reduce diet-related chronic disease.

University of Florida (Ebrahim Babaeian)

1. The generated knowledge advances our understanding of soil water dynamics and hydraulic properties and their role in agricultural water and nutrient management in sandy soils, thereby supporting the sustainability of surface and groundwater resources.
2. The developed data-driven modeling tools, when integrated with ground-based and satellite observations, will advance hydrologic modeling, improve soil health in agricultural soils, improve resilience to climate variability, and increase the security and sustainability of soil and water resources.

3. The hybrid modeling framework which couples the tau-omega radiative transfer model with machine learning algorithms allows field-scale surface-to-root zone soil moisture estimation and mapping for agricultural water management, which is an important capability that is currently unavailable from microwave remote sensing observations alone.

Connecticut Agricultural Experiment Station (Yingxue Yu)

Our research demonstrates that micro- and nanoplastics in soils are mobile and dynamically transformed by soil chemistry, weathering, and eco-corona formation, which together control their aggregation, transport, and persistence in vadose zone environments. We show that interactions with soil solutions and colloids can reduce differences among plastic types while enhancing aggregation and hetero-aggregation, and that agriculturally relevant plastic sources, including biodegradable plastic mulches and tire wear particles, can alter soil physical properties and soil–water relationships.
This work identifies key research priorities needed to assess and mitigate risks of micro- and nanoplastics in agricultural systems, including:

a) quantifying the occurrence, size distributions, and properties of micro- and nanoplastics from diverse agricultural sources;
b) determining how soil chemistry, eco-coronas, and weathering regulate plastic stability and transport;
c) evaluating impacts of plastic particles on soil physical properties, water availability, and crop performance;
d) assessing the transformation and mobility of conventional and biodegradable plastics under agricultural conditions; and
e) predicting long-term fate and off-site transport of micro- and nanoplastics in vadose zone environments.

Together, these findings provide a scientific basis for sustainable soil management and informed regulation of plastic contamination in agriculture.

Texas A&M University (Briana Wyatt)

Provided new information regarding the potential positive impacts of woody plant removal on groundwater recharge rates, including determination of areas where such work would be most and least beneficial. This information can be utilized by land managers to guide land management and remediation decisions.

Texas A&M University (Binayak P. Mohanty)

Our multi-scale process studies, linked numerical models, and innovative data analyses have provided efficient tools and techniques to address wide spectrum of challenges related to soil and environmental sciences, including water management, crop production, ecosystem resilience, climate forecasts, flood and drought prediction, groundwater recharge estimation, GHG emission, and soil pollution characterization. Specifically:

- Developed high resolution data for soil water management for precision agriculture.
- Provided better skills for hydrologic and climate models.
- Enhanced estimates for soil health and groundwater pollution.

University of Hawaiʻi at Mānoa (Jing Yan)

- Project under Objective 1 will strengthen the scientific and data foundations needed to understand and predict soil hydraulic behavior in Hawaiʻi's tropical environments. The completed literature review, data governance framework, metadata standards, and initial dataset curation have created a reliable structure for future modeling and analysis. These efforts support long-term improvements in forecasting soil hydraulic responses to climate and land-use change, guiding more informed decisions for agriculture, watershed management, and groundwater sustainability.
- Work under Objective 2 will advance mechanistic understanding of how microbial biophysical feedbacks influence soil hydraulic functions. By collecting and characterizing representative Oxisols, establishing controlled microbial experimentation methods, and conducting drying–wetting experiments, the project is uncovering how microbial activity shapes soil structure and water dynamics. These findings will ultimately improve soil hydraulic models, inform soil health and water conservation strategies, and support regenerative agricultural practices in tropical systems. Stakeholders gain new knowledge about the biological drivers of soil function, helping them manage soils for resilience and long-term productivity. By identifying saltwater evaporation in soils with textural heterogeneity, we gain greater capability to predict and regulate soil salinization in coastal environments.

University of Tennessee-Knoxville (Xi Zhang)

Provided local producers in Tennessee with baseline information on regionally appropriate management practices that improve soil functioning and promote the adoption of cover cropping practices to enhance productivity, profitability, and sustainability in the agroecosystem.

- Delivered lectures to growers and students on using conservation agriculture practices to improve agricultural system productivity.
- Received support from funding agency.
    - Zhang, X. Instrumentation Discovery Travel Grant: Proximal and remote sensing technologies for monitoring water dynamics in the vadose zone. Consortium of

Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI). Aug. 2025-Jul. 2026.

- Zhang, X. Advancing soil-plant-atmosphere modeling through SEC collaboration. Southeastern Conference (SEC) Visiting Faculty Travel Grant Program. Oct. 2025-Sep. 2026.
- Zhang, X. and Y. Fan. Unraveling the role of microplastics in shaping subsurface hydrologic processes and its implications for the migration of microplastics in the soil-groundwater environment. U. S. Geological Survey 104 Program. Sep. 2024-Aug. 2025.

Montana State University (Jack Brookshire)

Expansion of coniferous trees into formerly treeless rangelands has increased dramatically across the Northern Great Plains over the last several decades. Conifer encroachment has reduced forage utilization by herbivores, representing a cost in unrealized production estimated in the order of billions of dollars. Assessment of the reversibility of conifer encroachment requires an understanding of its soil biogeochemical legacy and effects of management intervention on forage production.

We work with land managers in central Montana to conduct large-scale experiments on the effects of conifer encroachment and its response to prescribed fire in rangeland ecosystems. Our findings show that conifer encroachment reduces soil nutrient availability over time, but that low to moderate severity fire can offset some of these losses by redelivery of carbon and nitrogen back to soils. Our findings help guide management tools designed to redress effects of conifer encroachment on rangeland productivity and soil fertility.

US Department of Agriculture, Agricultural Research Service, Agricultural Water Efficiency and Salinity Research Unit (Ray Anderson, Todd Skaggs)

No impact statement reported.

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