W4188 2023 Annual Report

W4188 Annual Meeting 2023 Agenda

Dates: Jan 3-5, 2024

Location: Rogers Auditorium, Desert Research Institute, 755 E Flamingo Rd, Las Vegas, NV 89119

Chair: Briana Wyatt

Secretary: Jingyi Huang

Treasurer: Robert Heinse

Virtual meeting link: https://tamu.zoom.us/j/99810099406 (full invitation on page 4)

Wednesday, January 3

8:00 am: Registration opens

8:30-10:00 am: Session I- Business Meeting

10:00-10:30 am: Break

10:30 am-12:00 pm: Session II- General Updates

10:30 am: Markus Berli, Statement from DRI, Nevada Research Update

11:00 am: Michael Young and Hassan Dashtian, Updates from UT Austin

11:30 am: Briana Wyatt, Updates from Texas A&M

12:00-1:00 pm: Lunch (catered @ DRI)

1:00-2:30 pm: Session III- Invited Speaker, Dr. Martin Schrön

Title: “Monitoring water in soil and snow with cosmic-ray neutrons across scales”

2:30-3:00 pm: Break

3:00-4:30 pm: Session IV- Sensors and Agriculture

3:00 pm: Scott Jones and Asghar Ghorbani, Utah State University Annual Report

3:30 pm: Ole Wendroth, Annual progress report University of Kentucky

4:00 pm: Thomas Harter, Orchard scale monitoring of recharge and nitrate leaching

4:30-5:00 pm: Poster Viewing 5:00-6:00 pm: Group social @ DRI (dinner on your own)

Thursday, January 4 8:00 am: Registration opens

8:30-10:00 am: Session V- W4188 renewal proposal discussion

10:00-10:30 am: Break

10:30 am-12:00 pm: Session VI- Sorptivity and Infiltration

10:30 am: Rose Shillito, The Nature of Sorptivity

11:00 am: Majdi Abou Najm, Agrivoltaics

11:30 am: OPEN

12:00-1:00 pm: Lunch (catered @ DRI)

1:00-2:30 pm: Session VII- Groundwater I

1:00 pm: Thijs Kelleners, Soil physics research at the University of Wyoming

1:30 pm: John Nieber, Downscaling GRACE TWS to HUC 12 watershed level

2:00 pm: Hoori Ajami, Understanding groundwater dynamics in mountainous catchments

2:30-3:00 pm: Break

3:00-4:30 pm: Session VII- Groundwater II

3:00 pm: Salini Sasidharan, Managed Aquifer Recharge

3:30 pm: Morteza Sadeghi, A New Algorithm for Vadose Zone Water Flow

4:00 pm: Helen Dahlke, Impact of vadose zone heterogeneity on managed aquifer recharge

4:30-5:00 pm: Poster Viewing 6:00-8:00 pm: Group Dinner at Hofbrauhaus (4510 Paradise Road, Las Vegas, NV 89169)

Friday, January 5 8:00 am: Registration opens

8:30-10:00 am: Session IX- Nanoplastics

8:30 am: Yingxue (Charlie) Yu, Transport of Biodegradable Nanoplastics in Porous Media

9:00 am: Markus Flury, Research Report from Washington State

9:30 am: OPEN

10:00-10:30 am: Break

10:30 am-12:00 pm: Session X- Modeling

10:30 am: Behzad Ghanbarian, Effect of data heterogeneity on machine learning

11:00 am: Jirka Simunek, HYDRUS Developments and Applications in 2023

11:30 am: Final comments and discussion

12:00 pm: Adjourn

Poster #	**Presenter**	**Title**
1	Lin Chen	An innovative framework to couple water flow, solute, and sediment transport at the hillslope scale
2	Jingyi Huang	Research updates from Uni-Wisconsin-Madison
3	Teamrat Ghezzehei	Trade offs in managing soils for multiple goals

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Minutes of W4188 Annual Meeting 2023

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Chair: Briana Wyatt

Secretary: Jingyi Huang

Treasurer: Robert Heinse

Participants:

In-person: Briana Wyatt, Jingyi Huang, Robert Heinse, Markus Berli, Michael Young, Hassan Dashtian, Sahar Bakhshian, Martin Schrön (invited speaker from Germany), Scott Jones, Asghar Ghorbani, Ole Wendroth, Thomas Harter, Rose Shillito, Manoj Shukla, Majdi Abou Najm, John Nieber, Hoori Ajami, Salini Sasidharan, Morteza Sadeghi, Helen Dahlke, Yingxue (Charlie) Yu, Behzad Ghanbarian, Jirka Simunek, Ray Anderson, Elia Scudiero, Todd Skaggs, Lin Chen, Yan Jin, Felix Ogunmokun, Laura Rosales Lagarde, Hannes Bauser, Shelby Inoye, Veronica Gasca-Alcanter, Robert Heinse, Sakiur Rahman,

Online: Thijs Kelleners, Ryan Stewart, Robert Horton, Andres Patrignani, Tyson Ochsner, Markus Flury, Teamrat Ghezzehei, Bhezad Ghanbarian, Robret Ewing, Isaya Kisekka, Vinit Seghal, Anish Saplota, Todd Caldwell, Floyid Nicolas, Spencer Jordan, Scott Bradford, Krletta Chief, Pai-Feng Teng, Hamid V.

Day 1, Jan 3, 2024, 8:30 AM-10 AM

1. Introductions of new/incoming members:

   UC-Davis, Helen E. Dahlke, hdahlke@ucdavis.edu

   Yingxue (Charlie) Yu, Connecticut Agricultural Experiment Station; yingxue.yu@ct.gov

   A. T. M. Sakiur Rahman, UC-Riverside, atmsakir@ucr.edu

   Hassan Dashtian, UT-Austin; hassan.dashtian@beg.utexas.edu

   Sahar Bakhshian, Bureau of Economic Geology, UT Austin; Sahar.bakhshian@beg.utexas.edu

   Felix Ogunmokun, UC-Davis; fogunmokun@ucdavis.edu

2. Annual Reports submission to Jingyi:

   Send to Jingyi Huang, by Friday, February 9th;

   Jingyi will send a follow-up email with the template and deadline.

3. Finances Update (Robert Heinse):

W2188 Meeting			ESS Excellence in Multistate Research Award	
2022	Carry Forward	$ 5,491.20	NIFA OTT	$ 15,000.00
2023	Registration	$ 4,550.00		
	Firefly	$ (3,650.96)	Proposal Writing	$ (3,072.00)
	DRI catering	$ (3,177.97)	Speaker	$ (2,500.00)
2023	Carry Forward	$ 3,212.27		
2024	Registration	$ 4,100.00+		

Rotating Fund: $3,212 + $4,100 - expenses of 2024 meeting

Multi-state Award $15,000: $3,072 proposal writing; $2,500 invited speaker; $10,000 less; need to spend it soon.

Discussion on ways to use the fund:

Scott Jones: student travel support; Tri-society meetings; Puerto Rico & San Antonia;

Michael Young: EGU meeting support;

Thomas Harter: UC-Davis: Toward Sustainable Groundwater in Agriculture, California, 2024;

Hoori Ajami: CUAHSI 2024 meeting: St. Paul, Minnesota;

Briana Wyatt: General use; Soil Physics Mentoring Committee to select the travel award:

Size: $1,500; 10 awards; Briana will take the lead to organize the review and Michael Young offers to help the review.

4. Selection of new Treasurer:

   Robert Heinse: Suggest an independent treasurer; Thomas Harter: UC-Davis, at least three PIs from the same institute and Thomas is willing to help; Robert will work with Thomas to work on transfer of the fund to UC-Davis after this year's meeting.

5. 2025 Annual Meeting Planning

   CES is Jan 7-10, 2025; Tentatively Jan 2 and 3, 2025.

6. 2025 Incoming chair/Secretary

   Ray Anderson accepts the nomination from Todd Skaggs as in-coming chair.

7. Other business:

   Ole Wendroth: thanks to Briana for the support; Ole: encourage participants to vote for society leadership.

Ryan Stewart: VZJ review paper; checklist. SSSA annual meeting schedule: Briana suggests people here at the meeting start organizing session proposals.

Yan Jin: Kirkham conference: Aug 19-22, 2025, Japan; 100 attendees and encourage young participants; more details will come later.

Day 2, Jan 4, 2024

Renewal proposal discussion

Briana: summarized the outline and current status of the proposal. Need inputs from participants on Section "Methods for each sub-objective (states to add their information)", from Pages 23 to 30.

Briana: Also need inputs for "Milestones" starting from Page 33. Scott Jones and Ole Wendroth mentioned that we can leave the state names in the proposal, but we can also add general milestones without states.

Ole mentioned that we could add some narratives describing the importance of soil physics to other disciplines. Majdi mentioned that we can add this as a new subobjective to Objective 4. Briana added this as "4.8 Improving interdisciplinary interactions".

Yan Jin mentioned that we soil physicists should reach out to other communities to emphasize the importance of soil physics in other disciplines. Ole mentioned a paper by Jan Hopmans in VZJ related to this. Thijs asked we may not have enough people working on soil structure and should we keep bullet points or complete sentences for objectives? Briana replied we can keep the bullet points.

Briana: do we need a website for the project/group? Ray Anderson: email list server still in North Dakota. Scott Jones mentioned that we should link this to SSSA website. Todd Skaggs mentioned that he can make a Python website. Ole mentioned that we should keep the participant list updated, not necessarily the website. Hoori mentioned we can create a Google Group in addition to the email list and offered to create that group and Scott seconded that. Martin Schrön mentioned that we should create a website to increase the public access of our group as he cannot find much information about our group before attending the meeting and hydrological communities in the US do not necessarily know this working group (they may know the people in this group). Yan Jin asked can we link our group to the SSSA SP&H Division Website? Todd offered to help create a website for our group. Thomas Harter mentioned that it can be demanding for a website manager to update all the publications from the members so we may only want to list the annual reports. Jan Jin mentioned that we can add members' lab links to the website. Majdi asked what we should include on the website. Yan mentioned that our group has a long history, and it is worth creating an external website to increase our publicity. Thomas Harter asked if a website could add additional information to the group? Ole mentioned that we can have a short introduction document ready instead of a website so that we can share it with the invited speakers for future meetings. Todd will start creating a website with a potential name "Soil Physics Working Group".

Jingyi ask for suggestions for 2025's meeting and he will send surveys to ask for preferences on dates and locations of dinner later this year.

Ole: Communication via SSSA discussion board is not very efficient. Should we create other ways to communicate? We can perhaps get emails from all the people and create an email list. Majdi mentioned "discord".

Accomplishments

Short-term outcomes

University of California Riverside (Hoori Ajami)

- Developed a method to assess the impacts of uncertainty in precipitation and temperature datasets on the water budget of a mountain catchment in the Sierra Nevada
- Developed a detection and attribution method based on the hydrologic modeling and time series data mining methods to understand causes of the Salton Sea decline in California
- Improved vegetation parameterization in integrated land surface –groundwater models using evapotranspiration partitioning data
- Contributed to developing a computationally efficient hydrologic model at hillslope scale

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 myself, my students, and my collaborators in multiple applications described below.

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%.
- Reached out to nearly 3,000 local, state, and federal policy- and decision-makers, researchers, and grower-representatives about nonpoint source pollution of groundwater and its sources, and about sustainable groundwater management.
- Provided grower representatives and regulators with efficient tools for assessing nitrate pollution from agricultural activities and to develop groundwater protection targets for 379 townships in the Central Valley.
- Developed a watershed model for the upper Scott Valley watershed
- Developed a water rights database for the Scott Valley watershed
- Developed a drain flow package for MODFLOW and employed that in the Scott Valley Integrated Hydrologic Model
- Supported the innovative development of the 2024 Scott-Shasta Valley Drought Emergency Order, which was approved by the State of California in 12/2023.
- Provided significant technical-scientific advising to local and state agencies to manage record snow-pack in California for groundwater storage benefits through MAR.
- Conducted two week survey of over 50 local and state members of Groundwater Sustainability Agency advisory committees and state agencies to evaluate role of various communication tools in engaging with highly diverse audiences.
- Completed development, scripting, photography, and video-recording for a national judicial Water and Water Law online training course.

- For the fourth time, taught COVID-19 appropriate, 5-week online shortcourse (5 hours/week) to introduce groundwater hydrology, to water law, California's Sustainable Groundwater Management Act, and review of several case studies on a range of aspects in developing groundwater sustainability plans. 85 attendees: water managers, attorneys, teachers, growers, staff from local and state agricultural organizations, NGO staff, regulatory agency personnel
- 2 Field trips, jointly with the Water Education Foundation: "Groundwater Tour" (1 day) and "Central Valley Tour" (3 days) to educate attorneys, teachers, growers, consultants, agency personnel, and policy decision-makers on groundwater, groundwater management, sustainability, groundwater-surface water interaction, and the nexus between groundwater and food production.
- 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

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 participated in numerous talks, presentations, and outreach meetings with different stakeholders. Furthermore and in collaboration with the German-American Chamber of Commerce, we launched California's first conference on Agrivoltaics, which was very well received and attended (attendance around 175) 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), American Farmland Trust (AFT) and the California Council on Science and Technology (CCST) among other agencies.

- 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, basil and peppers and the field was visited by a large number of stakeholders so it served as a demonstration site for introducing the prospects of the technology.

- In addition, my work on a significant review of soil infiltration came to fruition with having this review compiled, written and submitted for publication. The review, once published, will be the most comprehensive document on the theory and application of soil-water infiltration. We have identified and documented 138 unique infiltration models, and traced their theoretical and applied backgrounds to aid researchers and practitioners in understanding this complicated process.

University of California, Davis (Helen E. Dahlke)

- Conducted a recharge experiment on a fallow field to observe water flow and solute transport processes from the land surface to the groundwater table to a nearby groundwater monitoring well in response to intentional flooding for groundwater recharge.
- Collected vadose zone pore water samples and groundwater well samples for analysis for electrical conductivity, nitrogen species (NO3-, NH4+), oxyanions (e.g. U, As) and major cation and anions.
- Developed 1D single porosity and dual-porosity flow and transport models in HYDRUS to quantify water balance and flow and transport processes.

Desert Research Institute (Markus Berli)

- A model to describe the relationship between soil hydrophobicity and infiltration
- Methods to determine sorptivity of sub-critically water-repellent soil
- A method to assess the impact of fire on soil structure and hydraulic properties
- A model to simulate post-fire stream and debris flow

Washington State University (Markus Flury and Joan Wu)

- We demonstrated that biodegradable plastic plastics are equivalent to conventional polyethylene plastic mulches in terms of agronomic performance, effects on soil health, and yield quantity and quality. However, the cost of purchasing biodegradable plastic mulches is about twice to three times as much as for conventional plastic mulch films, preventing farmers from adoption of these new technology.
- The use of biodegradable plastic mulch films will reduce labor costs for removal of the mulch after harvest as well as disposal costs.
- We demonstrated that bicohar applications to soil can increase deep soil inorganic carbon sequestration.
- Water flow in soils is usually highly non-uniform and follows preferential flow paths. Stemflow and its below ground funnelling along roots and macropores may play an important role in the soil moisture redistribution in forest environments. Quantification of the stemflow and its contribution to groundwater recharge remains elusive. We developed a tracer-based technique using both isotopic and dye tracers to quantify amounts and spatial distributions of stemflow.
- Soil erosion by water is an ongoing agricultural and environmental problem the Inland Pacific Northwest. A unique 43-year (1940–1982) dataset of winter erosion measured on multiple agricultural fields in Whitman County, eastern Washington by Verle Kaiser, USDA Soil Conservation Service agronomist, showed annual erosion rates averaging 53.8 Mg ha−1, far exceeding the current Natural Resources Conservation Service tolerable limit of 11 Mg ha−1 yr-1 for the soils in the area. Kaiser's field data allowed us to compare the historical field-measured erosion rates with those simulated by the WEPP (Water Erosion Prediction Project) model.

University of Wyoming (Thijs Kelleners)

- Developed a coupled hydrogeophysical inversion model that uses surface-based electrical resistivity and seismic refraction measurements to determine subsurface structure and hydraulic properties

The University of Arizona (Markus Tuller)

- Measured stem water potential in real-time with microtensiometers in cotton in the course of a water stress experiment aimed at conserving irrigation water. This new technology is poised to significantly decrease water use of cotton, while sustaining yield and cotton quality. The results clearly demonstrate the effectiveness of microtensiometers for detecting water deficit stress and plant responses to atmospheric demand. The findings underscore the immense potential of microtensiometers to enhance irrigation management and water use efficiency in cotton cultivation, which could contribute to agricultural sustainability in water-limited regions.
- Evaluated the feasibility of high spatial resolution near-infrared remote sensing with unmanned aerial systems for soil moisture estimation to provide decision support for precision irrigation management. A new trapezoid model based on near-infrared transformed reflectance (NTR) and the normalized difference vegetation index (NDVI) was introduced and used for estimation and mapping of root zone soil moisture and plant extractable water. The performance of the proposed approach was evaluated via comparison with ground soil moisture measurements with advanced time domain reflectometry sensors. The results indicated that the estimates based on the NTR-NDVI trapezoid model were highly correlated with the ground soil moisture measurements. While the presented approach shows great potential for farm-scale precision irrigation management more research for different cropping systems, soil textures, and climatic conditions is needed to make the presented approach viable for the application by crop producers.

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

- An automated water retention measurement apparatus described in the 2022 report now has a publication describing the details in the Soil Science Society of America Journal (Dixon et al., 2023; https://doi.org/10.1002/saj2.20596).
- A NASA prototype root module design has been developed in collaboration with Space Dynamics Laboratory to provide ‘pick and eat’ vegetables in a ‘cut and regrow’ operation. Water and concentrated nutrient solution are mixed prior to fertigation of the crops. Porous ceramic tubes serve to provide both uniform irrigation within the root modules as well as providing a means of monitoring growth medium matric potential. Two different electromagnetic sensors monitor water content with a control algorithm maintaining a target range of water content. Root module fabrication will begin fabrication in early 2024.

University of Nebraska - Lincoln (Aaron Lee M. Daigh)

- Water quality network monitored in central North Dakota to evaluate linkages between soil microbial community structures and root zone losses of nitrates and phosphate in the vadose zone.

- Evaluated a GIS database of landslide conditioning factors in North Dakota, including geologic formations, pore water salinity, inclination, etc.
- Evaluated model simulations for salinity management and nitrate nitrogen leaching in sprinkler-irrigated maize production.
- Evaluated model sensitivity and error propagation for deep drainage and nitrate nitrogen leaching for combinations of model assumptions and time-averaging atmospheric inputs.

Oklahoma State University (Tyson Ochsner)

- Seasonal streamflow forecasting methods were developed incorporating remotely sensed soil moisture and terrestrial water storage data, which are increasingly available but thus far not widely utilized in operational streamflow forecasting. The resulting forecasts explained >70% of the variance in streamflow totals for the upcoming season in five watersheds across the US Great Plains.

Texas A&M University (Binayak P. Mohanty)

- Developed multi-model based soil moisture simulation approach under contrasting weather conditions. Findings indicated that the multi-model outputs were highly influenced both by the physical and optimization model structures. Overall, our new multi-model approach performed well in the test of transferability under different weather conditions.
- Developed a new method for effective hydraulic parameterization of catchment-scale aquifer. Using the Dupuit-Boussinesq aquifer in the National Water Model (NWM) showcased the dynamic coupling between vadose zone, ground water aquifer, and surface stream. This algorithm is being implemented in NOAA-Geo Fluid Dynamics Lab (GFDL) Earth Systems Model Land Model (LM) component now.
- Formulated a new advanced data fusion algorithm for generating high spatio-temporal resolution (daily 30 m) evapotranspiration (ET) estimates within large agricultural fields using eddy covariance and Landsat satellite based data. This provides potential for ET-based tools for precision water management in large agricultural fields.
- Using satellite remote sensing of precipitation, soil moisture, insitu soil texture, and monitored ground water table data, a physics-augmented machine learning (ML) tool was developed for estimating regional “preferential flow” to shallow groundwater systems across the continental USA. This is first-of-its-kind effort for preferential flow estimation at regional scale and found to be transferrable to other regions.

Texas A&M University (Briana Wyatt)

- Developed seasonal-scale streamflow forecasts for three surface water irrigation districts in the Great Plains region

New Mexico State University (Manoj K. Shukla)

- Irrigation with brackish, RO and produced waters changes soil physical properties and germination, growth. and actual evapotranspiration rates of cool season grasses as well as chile.
- Demonstrated higher water use efficiency for corn using micro-gravity drip irrigation system.
- Proper uncultivated land management can save water and maintain soil health.

University of Florida (Ebrahim Babaeian)

- Developed a physics-machine learning-based model for field scale estimation of root zone soil moisture with optical and microwave observations in sandy soils.
- Conducted in-situ soil moisture and hydraulic soil properties measurements for improved irrigation management in sandy agricultural fields.
- Supervising 7 graduate (MS/PhD) students (2 as a major advisor and 5 as advisory committee member).

Louisiana State University-Agriculture Center (Xi Zhang)

- Develop an interpretative framework linking cover cropping effects on soil structure to mass and energy fluxes for understanding biogeochemical processes, promoting the adoption of cover cropping in the mid-south, and developing management practices to improve agroecosystem services.
- Improve field water and nutrients management practices by delineating management zones based on the spatial variability of soil properties.

University of Kentucky (Ole Wendroth)

- Developed a saturated hydraulic conductivity map for a farmer's field (30 ha), 3 soil depths (16, 36, 56 cm); zones of relatively higher hydraulic conductivity proceed in the direction of watershed outlets.
- Derived temporal stability maps for crop yields and different crops. Across different years, corn yields behaved temporally stable, whereas wheat and soybean yields did not reveal strong, only modest temporal stability.
- Parameterized a 1-dimensional agroecosystem process model for simulating growth, yield and underlying soil water, nitrogen and aboveground processes (RZWQM2).

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- We developed methods to estimate soil hydraulic properties from thermal and electrical conductivities.
- We showed that applying composted materials to soils reduced runoff volumes, improved runoff water quality, increased vegetation establishment, and influenced heavy metal mobility.

- We investigated the performance of TDR and heat pulse sensors in high salinity soils and in heterogeneous soils.

Virginia Tech (Ryan Stewart)

- Our efforts to improve characterization of water-repellent soils can be used to identify and remediate such soils, which can help to safeguard water quality and quantity for the public.
- Our efforts to improve characterization of physical and hydraulic properties of soilless substrates allows producers to select growing media that has better water and nutrient-holding capacities, which helps to safeguard water quality and quantity for the public.
- One undergraduate student and two graduate students received training in data collection and curation, the scientific method and hypothesis testing, and scientific writing.

University of Delaware (Yan Jin)

- Introduced time-lapse zymography technique to the study of preferential flow and its impact on biogeochemical processes
- Improved understanding of how soil textural heterogeneity, i.e vertical textural contrast, affects saltwater evaporation through laboratory experiments
- Demonstrated the critical role of Plant Growth-Promoting Rhizobacteria (PGPR) in affecting soil evaporation under saline conditions
- Investigated how saltwater intrusion affects coastal soil in increasing ionic strength, sulfidation, alkalinization, and phosphorus (P) dynamics

University of Wisconsin-Madison (Jingyi Huang)

- Developed machine learning based high-resolution soil moisture model for the continental US
- Developed printed soil moisture and nitrate sensors for nutrient transport modeling
- Developed soil spectral libraries for estimating soil microbial functions

University of Minnesota (John L. Nieber)

- Providing results of analysis to identify the land surface sources of nitrogen from which nitrate ends up in wells and springs. The methodology is based on a technique developed by the USGS. These results are for the karst geological region in southeastern Minnesota, for which the US EPA is applying pressure on the agencies to reduce nitrate pollution.
- Provided some preliminary machine learning models for streamflow simulation to the NOAA-North Central River Forecast Center (Chanhassen, MN). Currently collaborating with the center to improve upon these models.
- Provided guidance for selecting locations for stormwater infiltration.
- Provided guidance for selection of infiltrometer measurement methods.

Outputs

University of California Riverside (Hoori Ajami)

Research findings were disseminated via:

- 7 publications in peer-reviewed journals
- 9 conference abstracts and presentations
- Taught 1 upper division undergraduate course on Spatial analysis and remote sensing for environmental sciences (4 units), and co-taught a graduate level course in Integrated Hydrologic Modeling (4 units).
- Served on 1 PhD dissertation committee, 1 MS thesis committee and participated in 2 PhD qualifying exams
- Served as an Associate Editor of California Agriculture, Hydrological Sciences Journals, and Journal of Hydrology

University of California Riverside (Jirka Šimůnek)

Research findings were disseminated via refereed journal publications, conference proceedings, and presentations at national and international meetings (see the publication section with 18 peer-reviewed journal articles below). HYDRUS models have been updated with several new capabilities and options that have been developed for various research projects, which in turn have been published in peer-reviewed journals.

U.S. Salinity Laboratory, USDA-ARS (Todd Skaggs, Ray Anderson, and Elia Scudiero)

UC-Riverside (Elia Scudiero)

Research findings were disseminated via:

- Research findings were disseminated via 4 refereed journal publications, a book chapter, an introductory chapter, a web-based database (https://www.handbook60.org/home/), and several in-person presentations at national and international meetings.
- Extension and educational activities, especially as part of a NIFA-SAS funded project.

University of California, Davis (Thomas Harter)

Research findings were disseminated via:

- 3 peer-reviewed publications
- 17 conference abstracts and presentations
- 68 invited presentations
- 1 conference special session organized
- 1 5-day short course organized and taught
- Audience reached in online or in-person presentations: 3,000

University of California, Davis (Majdi Abou Najm)

Research findings were disseminated via:

- 7 publications in peer-reviewed journals
- 5 abstracts and conference proceedings and several invited talks.

University of California, Davis (Helen E. Dahlke)

Research findings were disseminated via:

- five publications in peer-reviewed journals and one limited distribution in a grower journal
- 3 research reports
- 10 conference abstracts and presentations including one webinar
- Several media interviews to the public by CBS, NPR, New York Times, AgAlert, Thomson Reuters, Spectrum News, CapRadio
- Technical testimony to the Natural Resources subcommittee on Water, Wildlife and Fisheries of the US House of Representatives led by congressman Cliff Bentz (Oregon 2nd district) on water storage solutions.

Desert Research Institute (Markus Berli)

Our work focused on experimental and numerical models to describe the water dynamics of arid soils and their impact on desert hydrology with special focus on post-fire conditions.

Research findings were disseminated via:

- 7 publications in peer-reviewed journals
- 1 research report
- 13 conference abstracts and presentations

Washington State University (Markus Flury and Joan Wu)

Research findings were disseminated via:

- 12 publications in peer-reviewed journals
- 10 research reports
- 8 conference abstracts and presentations

University of Wyoming (Thijs Kelleners)

Research findings were disseminated via:

- 1 paper on hydrogeophysical inversion published in Water Resources Research
- 1 book chapter on soil salinity and water content sensing in press
- 2 conference presentations

The University of Arizona (Markus Tuller)

Research findings were disseminated via:

- 5 publications in peer-reviewed journals
- 7 book chapters

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

Research findings were disseminated via:

- 10 publications in peer-reviewed journals
- 2 book chapters
- 1 research report
- 19 conference abstracts and presentations

University of Nebraska - Lincoln (Aaron Lee M. Daigh)

Research findings were disseminated via:

- 3 publications in peer-reviewed journals
- 7 conference abstracts and presentations
- 1 book chapter

Oklahoma State University (Tyson Ochsner)

Research findings were disseminated via:

- 1 publication in peer-reviewed journals
- 1 conference abstract and presentations

Texas A&M University (Binayak P. Mohanty)

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).

- 8 journal publications
- 8 technical abstracts
- 2 Book chapters
- 3 project reports
- 14 presentations in national and international meetings

Texas A&M University (Briana Wyatt)

Research findings were disseminated via:

- 1 publication in peer-reviewed journals
- 2 research reports
- 3 conference abstracts and presentations

New Mexico State University (Manoj K. Shukla)

- Research results were disseminated in collaboration with various involved groups through 11 peer-reviewed journal articles, 1 text-bool, 6 conference contributions, and interactions with stakeholders and growers. RO-concentrated waste could be used to irrigate Atriplex species for livestock fodder, with further plans to irrigate with fresh water to remove accumulated ions as a potential sustainable waste management process.
- Attended Silk Road conference at Northwest A&F University, China.

University of Florida (Ebrahim Babaeian)

Research findings were disseminated via:

- 1 publication in peer-reviewed journals
- 2 book chapters published in Encyclopedia of Soils
- 6 conference abstracts and presentations (SSSA and AGU)

Louisiana State University-Agriculture Center (Xi Zhang)

Research findings were disseminated via:

- 4 publications in peer-reviewed journals
- 9 conference abstracts and presentations
- 2 articles in newsletter

University of Kentucky (Ole Wendroth)

Research findings were disseminated via:

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

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

Research findings were disseminated via:

- 29 publications in peer-reviewed journals
- 4 reports
- 40 conference abstracts and presentations

Virginia Tech (Ryan Stewart)

Research findings were disseminated via:

- 5 publications in peer-reviewed journals
- 2 peer-reviewed conference proceedings
- 3 conference abstracts and presentations

University of Delaware (Yan Jin)

Research findings were disseminated via:

- 6 publications in peer-reviewed journals
- Two research reports
- 4 conference abstracts and presentations
- Dissertation. Shane Franklin, 2023. Impacts of soil structural heterogeneity on biogeochemical processes across scales. University of Delaware

University of Wisconsin-Madison (Jingyi Huang)

Research findings were disseminated via:

- 8 publications in peer-reviewed journals
- 16 conference abstracts and presentations
- 2 US patents

University of Minnesota (John L. Nieber)

Research findings were disseminated via:

- 4 Publications
- 2 research reports
- 3 conference abstracts and presentations

Activities

University of California Riverside (Hoori Ajami)

- Improving vegetation parameterization in integrated groundwater-land surface models
- Comparing performance of micrometeorologic and isotopic methods for evapotranspiration partitioning
- Improving mountain system recharge prediction in the Sierra Nevada California
- Characterizing mountain flow path using geochemical data and mixing models
- Identifying major drivers of hydrologic change in the Salton Sea basin
- Assessing drought impacts on streamflow across the US

University of California Riverside (Jirka Šimůnek)

In 2023, we organized three short courses on using HYDRUS models. The first one was on-sight and was mainly for participants from Europe, while the second and third ones were mainly for participants from Nothern America (US and Canada) and Asia/Oceania, respectively. Over 100 students participated in these short courses.

- **Meetings attended**:

1. W4188 Western Regional Soil Physics Group Meeting, Las Vegas, Nevada, January 3-4, 2023.
2. W4128 Western Regional Microirrigation Group Meeting (Microirrigation: A sustainable technology for crop intensification and improved water productivity), online, January 23, 2023.
3. 7th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," Dept. of Soil Science and Geology, Czech University of Life Sciences, Prague, Czech Republic, April 20-21, 2023.
4. Annual Meeting of European Geosciences Union, Vienna, Austria, April 25-29, 2023.
5. Conference “Hydrology of Small Catchments 2023” (Hydrologie malého povodí 2023), 30.5.–1.6. 2023, Institute for Hydrodynamics, Czech Academy of Sciences, Prague, 2023.
6. Annual Meeting of Soil Science Society of America, St. Louis, Missouri, October 29-November 1, 2023.
7. Fall Meeting of American Geophysical Union, San Francisco, California, December 13-14, 2023.

- **HYDRUS Teaching**:

1. Teaching a short course “Modeling of water flow and contaminant transport in porous media using the HYDRUS and HPx software packages” organized by PC Progress, Prague, Czech Republic, April 17-19, 2023. Another instructors: M. Th. van Genuchten and Diederik Jacques (49 participants, mostly from Europe).

2. Teaching a short course "Modeling of water flow and contaminant transport in porous media using the HYDRUS software packages" organized by PC Progress, Prague, Czech Republic, online, September 6-7, 2023. Sole instructor (53 participants, mostly from the US and Canada).
3. Teaching a 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, online, September 12–13, 2023. Sole instructor (18 participants, mostly Asia and Australia, also some from Canada).

- **Public service:**

Guest Editor of the Vadose Zone Journal special issue in tribute to Dr. van Genuchten's Wolf Prize (2023-2024).

- **Invited Presentations**:

1. Invited presentation "*Numerical Modeling of Vadose Zone Processes using HYDRUS and its Specialized Modules*," Texas A&M University, College Station, Texas, October 18, 2023.

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.
- Performed and monitored Agricultural Managed Aquifer Recharge (AgMAR) pilot test in an almond orchard. Successfully recharged 30 ft of water in 30 days over each of three recharge basins. Monitored nitrate, water, environmental isotopes, and metal concentrations in the vadose zone and in groundwater.
- Developed HYDRUS-based approaches to modeling the vadose zone. Used AgMAR pilot test results to show that transport in the deep vadose zone is subject to preferential flow.
- Demonstrated the variability in deep vadose zone properties and resulting variability in recharge front behavior under AgMAR.
- Completed a 7-year trial of compost application in an almond orchard to determine the potential role of compost applications in mitigating greenhouse gas emissions from the orchard. Soil nitrous oxide (N2O) emissions were measured in compost trials and control trials, both under highly efficient irrigation. Soil without compost tended to higher N2O flux than soil with compost.
- Developed and implemented methodology to perform benchmark unimpaired flow analysis in a semi-arid intermontane basin with significant irrigation from groundwater and surface water resources, and with extensive dependence of dry season baseflow on groundwater discharge to streams. Utilized the same methodology to implement a wide range of future groundwater management scenarios that were jointly developed with a wide range of local and regional interest groups, including the local groundwater management agency, native American tribal members, local growers, local domestic well owners, staff from several environmental NGOs, local, regional, and state agency personnel, and the public at large.

- Provided decision-support through scenario modeling and extensive translational communications with a wide range of interested parties as part of a team that was charged with development of an emergency regulation to protect fish habitat while balancing public trust and public interest needs.
- Conducted numerous outreach and extension meetings to educate a wide range of audience members on groundwater issues.

University of California, Davis (Majdi Abou Najm)

- Activity 1: California's first Agrivoltaics conference: around 175 attendees from policy, agriculture, energy, academia and industry attended this conference which worked as a catalyst to connect all those groups together and push this new technology forward.
- Activity 2: Conduct a critical review on soil infiltration: we completed a full review tracing the evolution of infiltration theory that led to the development of 138 unique infiltration models over the past 2 centuries. This critical review is one of the most comprehensive documents on infiltration theory and will help identifying barriers and challenges, as well as recommending a roadmap for future directions.
- Activity 3: Agrivoltaics field experiment: we experimented three crops (tomatoes, basil and peppers) with 5 different shade/lighting treatments over a one-acre plot in the Campbell Tract at UCD. We tested how crops react to a wide range of light treatments, simulating different Agrivoltaics technologies.

University of California, Davis (Helen E. Dahlke)

- We analyzed the impact of large, continuous water applications (e.g. intentional flooding of agricultural soils for groundwater recharge) on pesticide leaching and mobilization. The intentional flooding (1.56 m/m2 of applied water) of an agricultural field for groundwater recharge caused the clear mobilization of four common pesticides (imidacloprid, chlorantraniliprole, methoxyfenozide, thiamethoxam) in the unsaturated zone. Peaks in pore water pesticide concentrations occurred within hours of applying floodwater in the near-surface soil layers and as delayed as 4-8 days in the deeper soil profile (1.2- 2.5 m). Concentrations of chlorantraniliprole were one order of magnitude greater in porewater than observed for the other three pesticides, likely due to its most recent (7 months prior) application time.
- Flow velocities and transit times of the infiltrating floodwater and the mobilized pesticides varied between 32.69 and 40.65 cm/days, clearly reflecting the differences in soil texture and particularly the sand content between the three profiles. Leaching efficiency of pesticides was greatest in the sandiest profile (84% sand) with 59-75% for imidacloprid, but less pronounced at the medium sand (61% sand) and less sandy (41%) profiles, with leaching efficiencies of 29-47% and 3.0-3.4%, respectively. Texture had little effect on water balance (6%), but determined whether preferential flow features and capillary barriers accelerated or attenuated pesticide transport into the deeper unsaturated zone.
- The fate and transport of pesticides within deep unsaturated zones (70 m) is most sensitive to their adsorption within the top soil layer, particularly in sandy profiles where adsorption is facilitation by soil carbon, and their degradation in complex profiles where restrictive layers slow transport.

The higher the sand content of the unsaturated zone, the deeper pesticides will be transported depending on pesticide type (40 m for thiamethoxam, methoxyfenozide, 75 m for chlorantraniliprole, imidacloprid). Presence of intermittent layers of clay, sandy loam, loam, or sandy clay loam are crucial in controlling the pesticides transport to groundwater.

- During Spring 2022, we conducted a recharge experiment at a fallowed almond orchard on three plots (694 m2, 735 m2, and 690 m2). Plots were flooded with surface water for 28 days, from May 3 (13:30) to May 31, 2022. Each plot was instrumented with vadose zone sensors (EC, temperature, VWC, O2, ORP, pore water suction cups, water level loggers), and sensors in a nearby groundwater well (EC, temperature, water level). At each site, 4.833 kg of KBr (i.e., 3.245 kg of Br-) was dissolved in approximately 100–110 gallons (380 L) of water and then applied over an area of 36.8 m2 within each plot. Based on the collected data, single- and dual-porosity models using the HYDRUS-1D software were developed at a temporal resolution of 10 minutes. Although all three plots were dominated by silty clay and silty clay loam, the profiles show progressively increasing fractions of sand from LS (44 %), MS (47 %) to HS (64 %).
- The collected data was used to develop and calibrate single-porosity and dual-porosity models in HYDRUS 1D to quantify solute transport, water flow and the water balance at each recharge site. Our modeling results show that the dual-porosity models (considering preferential flow) can better fit the arrival times of bromide fronts but cannot significantly improve the overall model performance. Preferential flow occurred due to the combined effects of dry antecedent soil moisture followed by flooding, dry climate, soil texture, and the incorporation of almond wood chips into the topsoil, etc. Preferential flow did not significantly impact the water balance calculations (within 2 %), but it decreased the travel times of bromide from the soil surface to different depths of the soil profiles by up to 38 %, compared to the predictions provided by the single-porosity model. In terms of groundwater recharge potential, HS showed a higher efficiency than MS or LS, but the differences were relatively minor (within 2 %). LS showed the highest degree of preferential flow, followed by HS and MS, and the overall average bromide transport velocities differed by up to 119 %. In brief, similar recharge efficiency can be achieved at sites with differing soil texture profiles but subsurface heterogeneity can have substantial effects on salt and contaminant transport dynamics, which should be considered when implementing Ag-MAR. This work was published in the journal Water Research (Zhou et al. 2023).
- We developed a 1D non-equilibrium (e.g. mobile-immobile) reactive transport HP1 (HYDRUS-1D and PHREEQC) model to be able to simulate O3– leaching and nitrogen transformation processes in agricultural soils. Most numerical modeling studies to date have only used simplified zero-order or first-order kinetic models when optimizing N budgets. However, field research has shown that temperature, soil moisture and other environmental conditions can have significant impacts on biogeochemical reaction rates. To highlight the suitability of a reactive nitrogen transport model capable of simulating nitrification, mineralization and denitrification processes dependent on environmental conditions, we compared this calibrated model to several other calibrated models representing simpler HYDRUS nitrate leaching modeling approaches (uniform flow, non-reactive, zero and first-order kinetics). Results show that the incorporation of conditional environmental factors such as temperature, soil moisture, and a proxy for oxic/anoxic conditions (percent pore-space filled) results in superior model performance representing the timing and magnitude of important biogeochemical processes when estimating cumulative NO3– leached from

the shallow vadose zone. In addition, using a physical non-equilibrium (i.e. dual-porosity type, mobile-immobile solute transport) approach improves model performance when estimating residual NO3– in the soil profile after water application events. This work was published in the Journal of Hydrology (Murphy et al. 2024).

- Conference Sessions:

  Zheng, Y., Dahlke, H.E. & S.A. Bradford. 2023. Climate Proofing Our Water Supply Through Upscaling Managed Aquifer Recharge. Session at the Fall Meeting of the American Geophysical Union, San Francisco, CA, USA 11-15 December, 2023.

Desert Research Institute (Markus Berli)

- Review fire-impacts on soil structure
- Evaluated methods to measure sorptivity of sub-critically water-repellent soil in the field
- Worked on an improved understanding of water infiltration, redistribution and evaporation from arid soils
- Modeling wildfire dynamics using WRF-fire for links with soil thermal alterations
- Modeling soil heat transport under wildfires and changes in soil constituents
- Shed light on the chemical nature of fire-induced soil water repellency

University of Wyoming (Thijs Kelleners)

- Maintained a soil moisture and rainfall measurement network consisting of 17 sites in Wyoming rangelands
- Maintained a distributed snow and soil monitoring network in the forested NoName watershed, Snowy Range Mountains, Wyoming

The University of Arizona (Markus Tuller)

- Developed a novel laboratory method for the retrieval of the soil water retention curve from shortwave infrared reflectance

Collaboration with Morteza Sadeghi (California Department of Water Resources), Sarem Norouzi (Aarhus University), and Scott Jones (Utah State University)

The soil water retention curve (SWRC) is an essential soil property that relates soil water content and matric potential. It plays a crucial role in soil water dynamics and the understanding of various hydrological phenomena at the land surface, including infiltration, runoff, evaporation, and energy exchange processes. In recent years, proximal sensing methods have shown great potential for retrieving this challenging-to-measure property from spectral reflectance. However, a physically-based approach is still lacking as current methods rely on empirical data-driven algorithms. We developed a novel physics-based laboratory method that, for the first time, enables direct estimation of the entire SWRC from saturated to dry using soil water content/reflectance data pairs within the shortwave infrared domain. The main hypothesis underlying the new method is that soil optical properties not only vary with soil water content but also with the pore scale distribution of capillary and adsorbed soil water. For evaluation, retrieved soil water retention curves of 21

soils that vastly differ in physical and hydraulic properties were compared to direct measurements. The results suggest that the new method is a rapid and efficient alternative to established SWRC laboratory measurement methods.

- Evaluated the effects of moss-dominated biocrusts on surface soil aeration in drylands Collaboration with Bo Xiao (Chinese Academy of Sciences), Giora Kidron (Hebrew University of Jerusalem), and Fuhai Sun (China Agricultural University)

The findings of this study show that biocrusts regulate the aeration and water retention of soils, which has significant ramifications for numerous biological and biogeochemical processes in dryland ecosystems and is of significance for the mitigation of soil degradation.

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

- In collaboration with Sadeghi and others, initiated Extension Water Initiative project aimed at providing estimates of biomass production on rangeland grazing and dryland farming operations. Installed monitoring stations at several locations for data collection and algorithm development. New machine learning algorithms are being tested to estimate the entire soil moisture profile from existing sensor within the soil profile.
- Held kickoff meeting at USU with Space Dynamics Laboratory and NASA representatives and contractors we are partnering with for 'pick & eat' vegetable production facility. Continued weekly and monthly meetings to integrate our root module mechanical and electrical components into support hardware.

University of Nebraska - Lincoln (Aaron Lee M. Daigh)

- Long-term research plots (established in the 1980s) and nine farmer fields instrumented with lysimeters were monitored for solution nitrate and phosphate below the root zones. Soil samples were also obtained to characterize the soil microbial community structures.
- A GIS database was updated and analyzed for >66,000 landslides in North Dakota, soil salinity, geology, topography, etc. maps. Data analysis was performed to characterize landscape conditioning factors that are associated with landslides in this region.
- Virtual experiments in HYDRUS were created to evaluate a gradient of irrigation-water-quality scenarios on soil salinization, nitrogen fertilizer, and crop water use. A total of 216 simulations in HYDRUS-1D were created to represent sprinkler irrigation in an arid, continuous maize system for 40 years using daily timesteps. Scenarios evaluated were for 1) deficit and over irrigation rates between 60 to 140% water requirements, 2) irrigation water quality from 0.5 to 6 dS/m, 3) nitrogen fertilizer rates of urea-ammonium-nitrate from 168 to 280 kg-N/ha, and 4) soil textures of sandy loam and clay loam.
- Virtual experiments in HYDRUS were created to quantify the extent of systematic errors for select scenarios of sprinkler-irrigated cropland in Nebraska when weather data inputs ranged from hourly to monthly timescales. Inputs included data from weather stations, irrigation scheduling and automated triggering, fertilizer applications (224 kg-N/ha urea-ammonium-nitrate), solute fate and

transport, and maize growth. Simulations included aggregating the weather data into timesteps of 1-hour, 6-hours, 1-day, 7-days, 14-days, and 30-days.

- Virtual experiments in HYDRUS were created to quantify uncertainty and sensitivity of free drainage (aquifer recharge) estimates to common model assumptions and levels of validation. Model assumptions included errors in saturated hydraulic conductivity, lower boundary condition, and pore-size-distribution model selection. The scale of linearity of deep drainage's sensitivity to pore-size distributions were also investigated.

Oklahoma State University (Tyson Ochsner)

- Revised and published paper describing our streamflow forecasting research in the Journal of Hydrology.

Texas A&M University (Binayak P. Mohanty)

- In 2023, 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, and carbon dynamics.
- Using various satellite observations for evapotranspiration and surface soil moisture at the footprint scale, we developed a lowpass filtering scheme for predicting root zone soil moisture. This provides the foundation for 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. The findings will eventually lead to better understanding of environmental and human health risks.
- Meeting organized

  Session Chair, Remote Sensing of Soil Processes, American Geophysical Union (AGU) Technical Session, AGU Fall Meeting, San Francisco, CA (2023)

- Meetings attended

  American Geophysical Union Fall Meeting, December 10-15, 2023.

- **Invited Presentations:**

1. Invited Speaker, Multiscale Soil Moisture and Hydrology: Applications, IEEE 2nd Soil Moisture School, Indian Institute of Technology Bombay, Bombay, India, March 15-17, 2023.

2.Keynote Speaker, Multiscale Soil Moisture and Hydrology: Applications, Workshop on Rejuvenating Watersheds for Agricultural Resilience through Innovative Development (REWARD) Program, World

Bank and Directorate of Soil Conservation and Watershed Development, Odisha, Indian Institute of Technology Bhubaneswar, Bhubaneswar, India, March 20-21, 2023.

3.Keynote/Guest of Honor Speaker, Global Soil Moisture Drydown and FLASH Drought Outlook, Center for Climate Smart Agriculture, Siksha O Anusandhan (Deemed to be University), Bhubaneswar, India, March 23, 2023.

4. Invited Speaker, Thermodynamic Bounds & Preferential States of Global Terrestrial Water Energy Coupling Using SMAP & other RS Data, Civil Engineering, Texas A&M University, College Station, Texas, April 10, 2023.

5. Invited Speaker, FLASH Tool, 2nd National Flash Drought Workshop of NOAA - National Integrated Drought Information System (NIDIS), UCAR, Boulder, Colorado, May 2-4, 2023.

6.Keynote Speaker, Soil moisture Remote Sensing, Land-Atmosphere Interaction, and Flash Drought Forecast, Workshop on Improving Climate Change Adaptation and Resilience in the Kalahari Basin with Earth Observation Data, Gaborone, Botswana, December 11-13, 2023.

Texas A&M University (Briana Wyatt)

- Completed work in developing remote sensing-based forecasts for hydrologic prediction
- Published findings in peer-reviewed journal

New Mexico State University (Manoj K. Shukla)

- Uncultivated land management with cover crops improve soil health in a limited-water environment.

University of Florida (Ebrahim Babaeian)

- Maintained field experiments with employing multiple-sensors (in-situ, proximal and remote sensing) to measure soil water characteristic in Florida' sandy soils.
- Continued to improve the accuracy of ConvLSTM models for short-, mid-, and long-term soil moisture nowcasts and forecasts based on ground and satellite remote sensing observations.
- Developing and testing a radiative transfer-machine learning-based model for estimating surface, near-surface, and root zone soil moisture in sandy soils.
- Instructing Environmental Soil Physics to undergraduate and graduate students from various disciplines.

Louisiana State University-Agriculture Center (Xi Zhang)

- Established fields with cover cropping management to explore soil water and gas fluxed as influenced by changes in soil structure under cover crops with different root traits.

- Investigated the influences of different cover crops on soil organic matter, water usage during the cover crop growing season and soil water storage, availability, and recharge for the following cash crop.
- Quantified the spatial variability of soil properties and their influences on field-scale soil water dynamics and crop growth.
- Served on SSSA 2024 Summer Conference Program Planning Committee.
- Attended ASA-CSSA-SSSA International Annual Meeting (St. Louis, MO. Oct. 29-Nov. 1).

University of Kentucky (Ole Wendroth)

- Intensive field campaigns for measurements of field soil water content, crop growth and yield, for collecting information to parameterize and run (validate) an agroecosystem model.
- Gathering first experiences in UAV remote sensing for collecting NDVI data in a 48-ha farmer's field
- Chair of Chief-Editors and Assigning Editor for Soil & Tillage Research (IF: 7.37); handled and reviewed 150+ manuscripts, assigned 900+ manuscripts.
- Responsibilities as Director of Graduate Studies in the Integrated Plant & Soil Sciences Program, University of Kentucky

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- We investigated correlations between thermal conductivity and water retention in unsaturated soils.
- We developed an empirical approach to estimate soil quartz content from particle density.
- We proposed a four-parameter based approach to simultaneously determine water content and organic liquid content from thermo-TDR measurements.
- We established four approaches to model non-linear salinity dependence on electrical conductivity.
- We evaluated energy fluxes and actual crop evapotranspiration (ETc act) rates of sycamore SRC during the establishment year in the Piedmont region.
- We analyzed yield and weather data from a long-term field study to determine the effect of various conservation tillage practices on crop productivity and stability.
- We determined the effects of compost amendment rate on saturated hydraulic conductivity and water retention to identify target compost rates for enhancing soil hydraulic functions.
- We determined thermal diffusivity (α) variations within three central Iowa fields to estimate the required number of measurement sites within each field to determine α at a specified precision.

Virginia Tech (Ryan Stewart)

- We continued our theoretical development of new models to describe infiltration in water-repellent soils.
- We performed field measurements using geophysics (e.g., electrical resistivity tomography) to better understand preferential flow processes.
- We developed a new method to calculate sorptivity, which affects infiltration rates of water into soil.

- We developed a new method to quantify hydraulic and physical properties of soils and soilless substrates using tension infiltrometer measurements.
- We installed instruments to analyze stormwater quantity and quality from utility-scale solar installations.

University of Delaware (Yan Jin)

- Conducted experiments to measure bromide tracer breakthrough and enzyme activities in columns with macropores
- The mechanisms by which enzymes are produced in relation to macropore flow were examined in model systems
- Collected monthly pore water samples from a coastal wetland, St. Jones Reserve, size-fractionated the samples into <1000 nm, <450 nm, <100 nm, and <2.3 nm to measure colloid and phosphorus concentrations
- Ongoing continuous monitoring of soil redox potential, pH, salinity, water level, and temperature at St. Jones Reserve using in situ Pt-redox probes, HOBO pH, and LTC sensors (4 locations along a salinity gradient, at 30, 60 and 120 cm depths at each location)
- Processed and synchronized time series data from field monitoring stations to facilitate model training
- Organized a sampling companion at St. Jones Reserve and collected samples of pore water, creek water, rain water over 12-hour tidal period. These sample are analyzed for stable H and O isotope signatures, which will be used to evaluate feasibility of using isotopes for better characterization of subsurface hydrology at the filed site

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. student, and three undergraduate students and serving on the committee members of three Ph.D. and one M.S. students
- Teaching Soil Physics (Soil Science 622), Environmental Monitoring and Soil Characterization for Earth's Critical Zone (Soil Science 327), and Using R for Soil and Environmental Sciences (Soil Science 585)
- Reviewed 35 manuscripts for various journals

University of Minnesota (John L. Nieber)

- Developed code (in Python) to implement a procedure for identification of sources of nitrate in groundwater.
- Developed code (in Python) for simulation of the transport of a chemical constituent in shallow groundwater. The codes works interactively with maps to locate the site of interest and to download information needed for developing the groundwater flow field. The transport model uses a

convolution integral approach to compute the solute concentration at a given point downgradient of the chemical source. The code is interactive and user-friendly.

- Developed a model for transient erosion of the inside of a soil pipe (subsurface erosion). The model was used in the simulation of experimental data developed by Glen Wilson at the USDA Soil Erosion Laboratory, Oxford Mississippi.

Milestones

Objective 1: **Connect new understandings of storage and transport of mass and energy to assess environmental change**

University of California Riverside (Hoori Ajami)

- Improve groundwater recharge estimation from mountain catchments by integrating hydrological and hydrochemical models
- Develop a data-driven method for estimating dynamic storage in mountain watersheds

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 myself, my students, and my collaborators in multiple applications described below.
- ***Hydrological Applications***

1. Gumuła-Kawęcka et al. (2023) evaluated the impact of climate change on groundwater recharge in shallow young glacial aquifers in Northern Poland by analyzing experimental data and a numerical model HYDRUS-1D.
2. Inoue et al. (2023) evaluated both experimentaly and numerically (using HYDRUS-2D) the repeated falling-head method for in situ measurements of saturated hydraulic conductivity using a single cylinder.
3. Zhou et al. (2023a) evaluated the impact of soil tension on isotope fractionation and transport, and interpretations of root water uptake origin using the newly developed isotope module of HYDRUS-1D.
4. Nasta et al. (2023) compared a virtual tracer experiment and particle tracking method (both carried out using HYDRUS-1D) to assess the temporal origin of root water uptake, evaporation, and drainage.
5. Zhou et al. (2023b) estimated the impact of vadose zone heterogeneity on agricultural managed aquifer recharge by analyzing experimental data and using HYDRUS-1D.
6. Zheng et al. (2023) studied water transfer mechanisms and vapor flow effects in seasonally frozen soils using experimental data and HYDRUS-1D modeling.
7. Chen et al. (2023) developed a computationally efficient hydrologic modeling framework to simulate surface-subsurface hydrological, solute transport, and erosioin processes at the hillslope scale by coupling the Kineros and HYDRUS-1D models. This is the second step in the development of the catchment scale model, which will additionally also include MODFLOW.
8. Šimůnek et al. (2024) provided a review of recent developments and applications of the HYDRUS computer software packages since 2016.

- ***Other Applications***

1. **Brunetti et al. (2023)** carried out an in-depth analysis of Markov-Chain Monte Carlo ensemble samplers for inverse vadose zone modeling.
2. **Shoorangiz et al. (2023)** used a fast hybrid technique to optimize multi-objective hydrant flushing in water distribution system with contamination events under uncertainty.

University of California, Davis (Thomas Harter)

- *Characterization and description of physical properties of the vadose zone:*

1) Completed sixth 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 initial analysis of AgMAR experiments with three replicate sites that include comprehensive soil-, deep vadose zone-, and groundwater-monitoring.

- *Multi-scale flow and transport including impacts from climate change:*

1) Initiated phase 2 vadose zone modeling of pre- and post-implementation nitrate leaching, over an 80 year period at a California nut crop site
2) 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

- *Applications of soil physics and biophysics in ecology and agriculture*

1) Successfully grew large crops of almonds with high-frequency low concentration fertigation technology.
2) Completed model and model scenario documentation for an integrated groundwater-surface water hydrologic model application in a semi-arid irrigated groundwater basin with significant baseflow and threatened salmon habitat.
3) Initiated 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)

- Outreach for Agrivoltaics technologies in California and beyond

1) California's first Agrivoltaics conference
2) Outreach via different webinars, venues and lectures

University of California, Davis (Helen E. Dahlke)

- Proposed a new reactive nitrogen transport model in HP1 (HYDRUS-1D and PHREEQC) to estimate mineralization, nitrification and denitrification processes as conditional kinetic reactions in response to changes in temperature, water content and oxidation-reduction potential.

- Nitrate, pesticides, and geogenic contaminants show a higher propensity for leaching and deep transport in the unsaturated zone in response to large continuous water application events (for intentional groundwater recharge) when the profile contains a high percentage of sand.

Desert Research Institute (Markus Berli)

- Model evaluation for water infiltration into hydrophobic soil
- Improved model to simulate water infiltration, redistribution and evaporation for arid soils.

Washington State University (Markus Flury and Joan Wu)

- A stemflow experiment was carried out in a Pinus sylvestris L. (Scots pine) forest. We used two artificial tracers to view and quantify preferential flow after stemflow infiltration into the soil: the Brilliant Blue FCF dye tracer and the deuterium isotope. Stemflow water was enriched with these two tracers and soil samples and soil profiles were analyzed for the spatial distribution of the tracers. We found that stemflow infiltrated through an annulus-shaped area around the tree base. We observed a heterogenous spatiotemporal soil moisture response to stemflow and the occurrence of shallow perched water tables around the tree trunk. Dye staining demonstrated that stemflow infiltrated primarily along the surface of coarse roots and through macropores. Deuterium and Brilliant Blue FCF concentrations were significantly correlated. Our results suggest that stemflow affects soil moisture distribution, and thus likely also groundwater recharge and surface runoff.

University of Wyoming (Thijs Kelleners)

- Use hydrogeophysical models to determine subsurface structure and hydraulic properties for mountain hillslopes
- Quantify the benefits of using hydrological versus geophysical data to calibrate hillslope-scale hydrological models

The University of Arizona (Markus Tuller)

- Developed a novel laboratory method for the retrieval of the soil water retention curve from shortwave infrared reflectance as a rapid and efficient alternative to standard laboratory methods

University of Nebraska - Lincoln (Aaron Lee M. Daigh)

- We were able to quantify a range of landslide conditioning factors across North Dakota. Of the 66,894 identified landslides, nearly 97% of those occurs in vadose zones with generally low pore water salinity and sodium adsorption ratios (SAR; i.e., <5.0 dS/m and <7.0 SAR, with maximum frequency occurring at 1.5 dS/m and 0.5 SAR) even though high pore water salinity and SAR is characteristic of many soils across the state.
- We were able to create evaluations on the magnitude and spatial trends in simulated salinity, drainage, and NO3-N distributions. As expected, subsurface salinity approached values of the

saline irrigation waters by the time of equilibrium. Relative crop water use decreased for 5 to 15 years before reaching an equilibrium between 87 to 52% as salts accumulated in the root zone. Annual NO3-N leaching generally ranged from 2 to 78% of the equivalent nitrogen-fertilizer applications due to a combination of salinity, water uptake, and drainage dynamics. Over 70% of annual NO3-N leaching and accumulation below the rootzone occurred 20 to 60 days after planting.

- We were able to quantify model errors in simulated water and nitrogen tended as input data timesteps increased. Errors were not linear or smooth as timesteps increased. Values often increased slightly before a larger decrease as timesteps increased. Deep drainage, soil water storage, and NO3-N leaching were generally similar among timesteps until 40 days after planting when divergence occurred in 2022. Divergence appeared gradually for deep drainage and soil water storage, but abruptly for NO3-N leaching. An estimated 20 to 75 kg-N/ha was lost as NO3-N to groundwater among all timesteps. Maximum errors induced by increasing timesteps were -43%, -38%, and -72% for deep drainage, soil water storage, and NO3-N leaching when compared to the control. These simulations suggest that larger and quicker errors occur for NO3-N leaching than deep drainage and soil water storage as timesteps deviate from true values.
- We were able to quantify uncertainty and sensitivity of free drainage (aquifer recharge) estimates to common model assumptions and levels of validation. We observed that all model setups closely matched the "accepted-as-true" dataset for soil water storage over time, which is often used during calibration or to confirm model validation. However, accumulative errors in deep drainage over one year ranged from 24 to -56% of the true drainage. These virtual experiments suggest that model validation (and possibly calibration) with only the soil water storage component of the water balance is inadequate to ensure model performance for the fate components of the water balance, such as deep drainage. We also observed nonlinear sensitivity of deep drainage estimates to the van Genuchten n parameter. These sensitivities also changed nonlinearly to conditions that influence temporal uniformity of water fluxes across the soil surface (i.e., with and without water use by crops, runoff vs ponding, uniformly vs non-uniformly distributed precipitation and irrigation). These outcomes suggest that uncertainties in deep drainage modeling may be expected to increase as precipitation and irrigation temporal patterns shift with climate change.

Texas A&M University (Binayak P. Mohanty)

- Newly developed two-way exchange scheme across surfacewater-groundwater-vadose zone interfaces provide improved predictive skill for water balance.
- Coupled soil moisture and ET dynamic characteristics were discovered across various landuse land covers and hydroclimates across the globe.
- Control of soil moisture and temperature on soil biogeochemical cycles were investigated for improving soil health and GHG emission processes.
- Using satellite remote sensing, critical evaporative fraction and soil moisture thresholds were established for water- and energy-limited systems.
- Our multi-decadal analyses showed the cause and effect in water balance driven by land use and land cover change (e.g., across the Amazon Basin).

New Mexico State University (Manoj K. Shukla)

- Prolonged drought conditions in New Mexico have led growers to use brackish groundwa-ter for crop irrigation. Desalination of the groundwater with reverse osmosis (RO) is possible, but the concentrated waste requires environmentally safe disposal, such as by irrigating native halophytic plants, Atriplex, which could be cultivated to feed livestock.
- Salinity-induced nutritional imbalances due to irrigation with brackish water could adversely affect crop production. The five saline treatments were tap-water of EC 0.6, brackish water of EC 2 and 3, and reverse osmosis (RO) concentrate of EC 4 and 6 dS/m. The higher concentrations of Na, Mg, Ca, K, and Cl in soil and irrigation water increased Na and Mg but decreased K and Ca concentrations in plant organs. The accumulations of micronutrients (Fe, Mn, Cu, B, and Al) except Zn in the whole plant decreased with increasing salinity levels. However, the amounts of Mn, Fe, B, and Al were positively correlated to yield at a significant level.

Louisiana State University-Agriculture Center (Xi Zhang)

- Improve mechanistic understanding of how cover crops root activities influence soil structure development and thus water and gas fluxes in agroecosystem.
- Quantify the responses of soil organic matter and soil physical health to cover cropping under diverse management practices.

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- We developed new insights on correlations between soil thermal conductivity and water retention. The critical water content (θc) of a thermal conductivity curve was strongly correlated to selected soil hydraulic and physical properties, such as water contents at wilting point (θpwp), inflection point (θi), and hydraulic continuity (θhc) determined from measured soil water retention curves, SWRCs, for a 23-soil calibration dataset. We investigated the underlying mechanisms for correlations between θc with θhc which dominated both heat transfer and water flow. This study provides the foundation for future studies to further investigate the general relationship between thermal conductivity versus water content curves and water retention curves.
- We related the critical water content (θc) of the percolation-based effective-medium approximation, P-EMA, model to the pore size distribution parameter (m) of the van Genuchten model and established a pedo-transfer function to estimate the van Genuchten model parameter α from soil properties and P-EMA parameters. Three approaches were developed to estimate the van Genuchten model parameters from thermal conductivity, λ(θ), measurements, porosity, sand and clay contents. The three approaches were then validated on six independent soils, and results showed that all of the approaches estimated θ well and outperformed earlier methods.
- The bulk electrical conductivity (σ) of porous media, as a function of pore fluid conductivity (σw), exhibits non-linear behavior (convex upwards) at low salinity and transitions to linearity behavior at high salinity. Classical models have difficulty in matching both low and high salinity conditions. We established asymptotic limits at zero and infinite salinity, and then bridged the gap between two extremes by employing four configurations: (Padé approximant, Maxwell-Garnett, Bruggeman and linear). We evaluated the performance of the four configurations in comparison to five existing models using datasets obtained from literature. The new models were superior to the existing

models. The new models are particularly advantageous in scenarios involving the interpretation of electrical data in low salinity environments.

Virginia Tech (Ryan Stewart)

- To publish the results of laboratory experiments aimed at quantifying gas diffusion rates and pore size distributions of nursery substrates, by June 2024.

University of Delaware (Yan Jin)

- We found that dispersion increases enzyme activity and enzyme activity is most prominent in the vicinity of macropores
- Our results imply that dispersion, soil carbon mineralization, and carbon accrual are linked
- Our findings from the field study at St. Jones Reserve improve understanding of biogeochemical cycling of OC and P in redox-driven environments
- Additionally, it provides a solid background for future research on the depth-distribution of colloidal OC in both freshwater wetland and marshlands.
- Development of advanced ML and DL-based models can contribute to the resilience planning in the face of climate-related challenges in the wetland.
- Predictive and forecasting models can provide valuable information for policymakers and funding agency (e.g., Department of Defense) to make evidence-based decisions related to marshland conservation and management

University of Minnesota (John L. Nieber)

- Improve ability to predict streamflow (floods, droughts, etc) based on some form of measurement (observation wells, soil moisture, satellite, etc.) of water storage in the watershed, by December 2024.
- Improve the ability to simulate streamflow with machine learning models by incorporating dynamic sub-watershed scale data, by December 2025.
- Improve simulation of subsurface erosion in soil pipes through implementation of fundamental particle detachment models, by December 2025.

Objective 2: **Develop and test new methods and models to improve the quality of soil information and knowledge**

University of California-Riverside (Hoori Ajami)

- Improve vegetation parameterization in land surface models
- Improve methodologies for sensitivity analysis and quantifying uncertainty in hydrologic models
- Develop pedo-transfer functions for dual-permeability models

U.S. Salinity Laboratory, USDA-ARS (Todd Skaggs, Ray Anderson, and Elia Scudiero)

UC-Riverside (Elia Scudiero)

- **New approaches to measuring field-scale soil salinity in drip-irrigated systems.** Sensors measuring soil apparent electrical conductivity or ECa, paired with a geo-referencing system (e.g., GPS), can be used to map soil properties, such as soil moisture and texture. Micro-irrigated orchards are often characterized by small scale heterogeneity of soil moisture: soil is very wet along the tree rows and much drier in the alleys between tree rows. The use of ECa in such heterogeneous systems is under investigated. Our research shows that ECa measurements are remarkably different when taken in wetter vs. drier locations in micro-irrigated fields. The ECa measurements should be taken over wet soil profiles to increase their accuracy. Therefore, we devised a novel field vehicle that allows taking field measurements along the micro-irrigation emitters. Additionally, the vehicle was equipped with a gamma-ray spectrometer, which is known as a reliable predictor for soil texture and can be used to improve the accuracy of soil moisture and texture maps based on the ECa measurements. The accomplishments of this work will benefit growers, agricultural technology industry, and soil scientists by increasing the reliability of ECa technology for soil mapping and irrigation management in micro-irrigated orchards.
- **Determination of irrigation timing and phase 1 soil evaporation with daily satellite imagery.** Satellite-based remote sensing models have long been used to estimate crop water use and schedule irrigation. However, monitoring irrigation using previous generations of satellites was challenging as many of them had either low temporal resolution (frequency) or spatial resolution (pixel size) or both. In this study, we used a recently launched cubesat satellite constellation (Planet) with high spatial and temporal resolution (daily 3 meter spatial resolution) data to estimate crop water use and evapotranspiration (ET) using the water and energy balance model BAITSSS. Water balance models including BAITSSS need irrigation dates to initiate the model and for conducting water balance thereafter during the crop season. These irrigation events can be inferred by evaluating at surface reflectance of individual spectral bands as well as the combination of these bands such as the normalized differential vegetation index (NDVI) and moisture index. Our results showed that daily Planet data can detect the onset of irrigation, including the critical first irrigation event, and some successive irrigation events thereafter during the partial cover period. This irrigation detection improves model performance without the need for farmer or user supplied irrigation data. The results also indicate that Planet data can help to improve ET but also can be beneficial to overall crop water management through detection of irrigation onset. These results are of interest for irrigation managers and farmers who need a robust and easy to use crop water use model for irrigation scheduling and water deliveries.

University of California, Davis (Majdi Abou Najm)

- Conduct critical review on infiltration:
- Completed review on 1D and 3D problems
- Completed review on empirical models
- Summarized the modeling frameworks of 138 models
- Completed and submitted a manuscript for publication.

University of Wyoming (Thijs Kelleners)

- Develop and test a coupled hydrogeophysical inversion model to determine the subsurface structure and hydraulic properties of hillslopes

The University of Arizona (Markus Tuller)

- Evaluated the feasibility of high spatial resolution near-infrared remote sensing with unmanned aerial systems for soil moisture estimation to provide decision support for precision irrigation management.

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

- USU identified and evaluated a range of readily available granular media that could be used to calibrate and validate thermal property measurements of Heat Pulse sensors and established a packing (i.e., using multiple sieving pluviation) and a wetting/draining method that resulted in highly repeatable granular media conditions for thermal property determinations. We identified and tested a variety of granular media including spherical- (quartz sand, glass beads), angular- (crushed media) and aggregated- materials. Overall, thermal property values ranged from 0.51 to 3.68 MJ m−3 K−1 for heat capacity, Cv, 0.13 to 3.73 W m−1 K−1 for thermal conductivity, λ, and 0.17 to 1.5 mm2 s−1 for thermal diffusivity, κ. We demonstrated that with the MSP method, it was possible to achieve highly repeatable bulk density, ρb, values and thermal property values for several commercially available granular materials. We recommend this approach as a standard calibration method based on 1) repeatable granular media packing and 2) standardized thermal property values for coarse granular media at targeted uniform water content distributions.
- USU designed, fabricated and tested an automated system to collect wetting- and drying-water retention data from coarse porous media, which output the initial drying process beginning with a fully saturated sample (h = 0 cm) and yielded subsequent wetting- and drying-water retention data. Our automated water retention measurements in quartz sand (ASTM-C778) exhibited maximum- and minimum-standard deviation in volumetric water content of 0.013 and 0.00044 cm3 cm–3, respectively. Parameters of the hysteretic water retention model of quartz sand were characterized using highly repeatable measurements. Results of this research included the creation of an automated water retention system and the well-characterized hydraulic parameters for the original well-graded- and narrowly sieved particle sizes of the ASTM-C778 quartz sand.

Texas A&M University (Binayak P. Mohanty)

- Developed model for dynamic coupling of vadose zone, ground water, and stream flow. This algorithm is now being implemented in National Water Model (NWM) and GFDL Earth Systems Land Model (LM). Additionally, soil parametrization concepts supplement these coupled process models. This enhances the overall skill of hydrologic and global circulation models.
- Developed model for downscaling ET products for precision water management at a farm scale. This is a significant breakthrough for soil management.
- Developed functional relationships between soil moisture and biogeochemical cycling. This improves the coupled hydrologic and biogeochemical modeling skills in unsaturated environment leading to soil, water, and air quality assessment.
- Developed model for estimating regional scale effective preferential water flow to shallow ground water table using remote sensing data, soil physics concepts, and machine learning tools.

University of Florida (Ebrahim Babaeian)

- Completed development of physics-machine learning-based models integrated with optical and microwave for estimating surface, near-surface, and root zone soil moisture at the field scale.

University of Kentucky (Ole Wendroth)

- Progressing with hydrologic parameterization of the RZWQM2 – How sensitive is the model to site specific soil information? Is landscape position an effective indicator for soil hydraulic property parameters?
- Landscape position affects crop yield more than nitrogen fertilizer application rate between rates of 100-220 kg N/ha.

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- We established a relationship to use the four thermo-TDR measured soil properties (dielectric constant, electrical conductivity, volumetric heat capacity, and thermal conductivity) to simultaneously determine soil water content, θw, and non-aqueous phase organic liquid content, $\theta NAPL$. The new four-parameter-based approach to estimate $\theta NAPL$ was found to be more accurate than existing two property-based approaches, and enabled suppression of the effects of measurement errors by the optimization processes and allowed highly sensitivity parameters to cover for shortcomings in low sensitivity parameters. Use of thermo-TDR sensors with the four-parameter-based approach to determine $\theta NAPL$ can contribute to various NAPL soil contamination studies as a NAPL content quantifying approach.
- We presented an empirical equation to estimate quartz content (fquartz) values from soil particle density (ρs). The empirical equation was developed from two published datasets and its performance was evaluated by comparing measured values to estimated values. Results indicate that the new empirical equation provides a simple and easy approach to estimate fquartz as an input to thermal conductivity models.

Virginia Tech (Ryan Stewart)

- To publish the theoretical framework and initial results from our system to quantify hydraulic properties of porous media using tension infiltration, by April 2024.
- To build and test a new system for monitoring soil particle movement during erosion, by November 2024.
- To test our new system for distributed measurements of CO2 fluxes using low-cost sensors, by October 2024.
- To continue the development of modeling frameworks to understand soil water repellency and preferential flow processes in soils, by December 2024.

University of Delaware (Yan Jin)

- Conducted a comprehensive literature review on existing machine learning (ML) and deep learning (DL) based approaches related to wetland hydrology and biogeochemistry
- Developed ML-based models to predict changes in salinity and redox potential based on multivariate input variables
- Implemented DL-based models to forecast changes in salinity and redox potential for marshland
- Conducted experiments that simulated the processes of soil evaporation in porous media with vertical textural contrast to examine its effects on evaporation, saltwater retention, and salt precipitation
- Conducted experiments to examine effects of a rhizobacteria, UD1022 on water retention and evaporation under different salinity
- Monitored soil water and salinity changes, and collected pore water samples in saltwater marshland to identify impacts of saltwater intrusion on soil salinization in coastal regions
- Investigated how saltwater intrusion affects coastal soil in increasing ionic strength, sulfidation, alkalization, and phosphorus (P) dynamics

University of Wisconsin-Madison (Jingyi Huang)

- Models and an R package were developed for predicting surface and rootzone soil moisture dynamics across the continental USA
- Sensors developed for monitoring soil water and nitrate contents and gas emissions from soils
- New vis-NIR spectral models developed for assessing soil microbial properties

Objective 3: **Integrate scale-appropriate methods to improve decisions related to the management of soil and water resources.**

University of California-Riverside (Hoori Ajami)

- Develop watershed scale models to assess the impacts of climate variability and agricultural management practices on streamflow and lake-groundwater interaction
- Develop computationally efficient modeling frameworks for watershed scale simulations

University of California Riverside (Jirka Šimůnek)

- ***The Use of Hydrus Models to Evaluate Various Irrigation and Fertigation Problems - Agricultural Applications***

1) Yang et al. (2023) used laboratory measurements and model simulations to evaluate the effects of water application methods (ponded, intermittent, unsaturated) on salinity leaching efficiency in different textured soils.
2) Guo et al. (2023) used the HYDRUS-3D software package to optimize the irrigation strategies in a mulched drip irrigation system with a shallow brackish water table in Xinjiang, China.
3) Lazarovitch et al. (2023) reviewed the use of the HYDRUS software package for modeling irrigation and related processes. The review included sprinkler, furrow, basin, and drip irrigation techniques, and fertigation and chemigation processes, and salinity and sodicity problems.
4) Hu et al. (2023) evaluated soil water dynamics under a no-tillage system with residual plastic film mulching in an arid region of western China using HYDRUS-2D.
5) Zhang et al. (2023) quantified water and salt movement in a soil-plant system of a corn field using HYDRUS (2D/3D) and the stable isotope method.
6) Phogat et al. (2023a) evaluated the sustainability of a rainfed wheat production system in relation to water and nitrogen dynamics in the soil in the Eyre Peninsula, South Australia, using the HYDRUS-1D model.
7) Phogat et al. (2023b) optimized irrigation of wine grapes with brackish groundwater for managing soil salinization using the HYDRUS-1D model.

- ***Fate and Transport of Various Substances (Carbon Nanotubes, Viruses, Explosives)***

With another member of the W4188 group, Scott Bradford we worked on various aspects of the transport of pathogens in the subsurface.

1) **Zhang et al. (2023)** evaluated using experimental data and HYDRUS-1D modeling the significance divalent cation contributions to the co-transport and deposition of functionalized multi-walled carbon nanotubes in porous media in the presence of bentonite or goethite nanoparticles.

University of California, Davis (Majdi Abou Najm)

- Agrivoltaics experiment:

1) Experimenting with different crops (tomatoes, basil and peppers);
2) Experimenting with different light/shade treatments (red, blue, red-yellow-orange, full sun, full shade)

Washington State University (Markus Flury and Joan Wu)

- We studied the interactions of earthworms with microplastics in a natural environment with environmentally realistic plastic concentrations. We investigated whether earthworms would ingest microplastics and incorporate them into their bodies and cast, and whether microplastics would alter the intestinal and soil microbiome. Lumbricus terrestris was exposed to two types of microplastics, biodegradable polybutylene adipate terephthalate (PBAT) and low-density polyethylene (LDPE) in mesocosoms filled with natural soil. Microplastics were mixed with poplar leaves, and earthworms were allowed to forage for food. We observed microplastics particles in earthworm casts and guts. Raman spectroscopy indicated that PBAT in guts and cast had degraded to some extent; however, LDPE remained unchanged among the different samples. Microbial analysis showed that soil and casts has similar microbial communities; however, they were significantly different from the gut samples. Microplastic treatments did not result in a statistically significant change in bacterial richness, diversity, or community composition for soil, casts, or guts compared to controls. Taken together, our results suggest that, at environmentally realistic concentrations and short exposure times, PBAT and LDPE microplastics do not have adverse effects on Lumbricus terrestris earthworms.
- We measured the physical properties of a silt loam in response to the incorporation of polyester fibers and polypropylene granules over a wide range of concentrations. We further elucidated the underlying mechanisms by determining the role of microplastic shape and the baseline effects from the amendment of soil particles. The incorporation of microplastics into soil tended to increase contact angle and saturated hydraulic conductivity and decrease bulk density and water holding capacity, but not affect aggregate stability. Polyester fibers affected soil physical properties more profoundly than polypropylene granules, due to the vastly different shape of fibers from that of soil particles. However, changes in soil properties were gradual, and significant changes did not occur until a high concentration of microplastics was reached (i.e., 0.5% w/w for polyester fibers and 2% w/w for polypropylene granules). Currently, microplastic concentrations in soils not heavily polluted with plastics are far below these concentrations, and results from this study suggest that microplastics at environmentally relevant concentrations have no significant effects on soil physical properties.
- Plastic pollution caused by conventional plastics has promoted the development and use of biodegradable plastics. However, biodegradable plastics do not degrade readily in water; instead, they can generate micro- and nanoplastics. Compared to microplastics, nanoplastics are more likely to cause negative impacts to the aquatic environment due to their smaller size. The impacts of biodegradable nanoplastics highly depend on their aggregation behavior and colloidal stability, which still remain unknown. We studied the aggregation kinetics of biodegradable nanoplastics made of polybutylene adipate co-terephthalate (PBAT) in NaCl and $CaCl_2$ solutions as well as in natural waters before and after weathering. We further studied the effect of proteins on aggregation

kinetics with both negative-charged bovine serum albumin (BSA) and positive- charged lysozyme (LSZ). Both BSA and LSZ promoted the aggregation of pristine PBAT nanoplastics, and LSZ showed a more pronounced effect. However, no aggregation was observed for weathered PBAT nanoplastics under most experimental conditions. Further stability tests demonstrated that pristine PBAT nanoplastics aggregated substantially in seawater, but not in freshwater, and only slightly in soil pore water; while weathered PBAT nanoplastics remained stable in all natural waters. These results suggest that biodegradable nanoplastics, especially weathered biodegradable nanoplastics, are highly stable in the aquatic environment, even in the marine environment.

- We applied the WEPP model to simulate soil erosion in eastern Washington and evaluate the interactive effects of climate and management, in addition to topography and soil, on water erosion in the study area. We compared the simulation results with Kaiser's historical field dataset and elucidate the long-term soil erosion trend.

University of Wyoming (Thijs Kelleners)

- Quantify the benefits of using surface and airborne electromagnetic induction measurements to calibrate catchment-scale hydrological models for streamflow prediction

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

- USU presented analysis from four years of soil moisture data yielding evapotranspiration estimates from four common vegetation types in a mountain region of the intermountain west. Those ET estimates were compared with eddy covariance estimates of ET over the same period from a grass/forb ecosystem. Results indicate vegetation type showed no significant difference (<5%) in ET comparing four growing seasons, except where abnormally wet conditions occurred. Four-year mean cumulative growing season ET estimates for aspen, deep-rooted conifer, shallow rooted conifer, sage, and grass were 43.0, 40.2, 28.7, 28.8 and 26.1 cm, respectively.

Oklahoma State University (Tyson Ochsner)

- Project completed and paper published wrapping up our planned contribution under this multi-state project.

Texas A&M University (Binayak P. Mohanty)

- Our high space-time resolution ET and soil moisture products provide the basis for water management in precision agriculture in large agricultural fields.
- Our multi-model soil moisture simulation provides the effective platform for futuristic resource management of dry, wet, or normal years.
- We developed a global flash drought monitoring tool using surface soil moisture from SMAP satellite. This tool is now being used by many across the globe for operational drought monitoring and management.

Texas A&M University (Briana Wyatt)

- Completed development of seasonal-scale streamflow forecasts for three surface water irrigation districts in the Great Plains region

Louisiana State University-Agriculture Center (Xi Zhang)

- Analyze the spatial variability of soil properties and its influences on soil water dynamics and solute transport at the field scale.
- Evaluate the water use by cover crops to quantify the impact of cover cropping on soil water storage, availability, and recharge in the fields.

University of Kentucky (Ole Wendroth)

- Field measurements of saturated hydraulic conductivity (borehole permeameter) that were taken at grid spacings in a farmer's field (30 ha) of 70 m resulted in a spatial range of dependence of approximately 300 m reflecting landscape topography and associated soil textural variability. For decreasing the uncertainty of estimating the local saturated hydraulic conductivity, a nested measurement design is recommended and the spatial correlation to a secondary variable that can be measured with a lower time and labor effort.
- Combine harvester crop yield data, processed, and aggregated to 20 by 20 m raster exhibit temporal stability of crop yields. Next, governing soil variables and landscape topographic indices will be tested as spatial variables related to high, low and intermediate yields.

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- We evaluated energy fluxes and actual crop evapotranspiration (ETc act) rates of sycamore SRC during the establishment year on marginal land in the Piedmont physiographic region of NC, to better understand the factors controlling the evaporative demand of sycamore and its sensitivity to drought stress during establishment. Measurements suggested that trees may not yet have developed a root system sufficient to sustain transpiration during dry spells and that water use of the sycamore field was highly coupled to precipitation during the establishment year.
- We analyzed yield and weather data from a 28-year tillage study in the southeastern U.S. piedmont region to determine the effect of various conservation tillage practices on maize and soybean productivity and stability under a variety of growth conditions. Previous reports from the site have likewise indicated little differentiation in soil health between tillage systems over the life of the study. Results suggest that surface residue management may be an important driver of system performance, possibly more so than overall soil health.
- We determined the effects of compost amendment application rates on saturated hydraulic conductivity (Ks) and water retention in order to identify target compost rates for enhancing soil hydraulic functions for three soil textures (sandy loam, silt loam, and sandy clay loam). Results suggest soil texture should be taken into consideration when choosing a compost application rate

in order to achieve soil improvement goals. Hydrologic benefits may be limited even at a high compost amendment application rate if soil is compacted.

- We determined thermal diffusivity (α) variations within three central Iowa fields under long-term tillage practices and to estimate the required number of measurement sites within each field to determine α at a specified precision. Three fields received different tillage operations: one was moldboard plowed followed by spring disking (MP), another was chisel plowed followed by spring disking (CP), and the third was ridge no-tilled (RN) slot planted. The minimum number of samples needed to obtain a confidence interval of 7 cm2 h−1 for α was two, five, and seven, respectively, for the CP, RN, and MP fields. The MP field had the largest mean α value and required the largest number of samples to determine α at a specified precision.

Virginia Tech (Ryan Stewart)

- To provide recommendations based on the results of our study on gaseous and leaching losses of nitrogen from common fertilizers in cotton production, by December 2024.
- To provide recommendations for vineyard soil management that enhances wine-grape quality, by December 2024.

Impact Statement

University of California-Riverside (Hoori Ajami)

- This research has focused on understanding of groundwater recharge processes in mountain catchments and quantifying streamflow response to meteorological droughts. As part of these efforts, we shared our research results with stakeholders such as NGOs and Groundwater Sustainability agencies in the Kaweah River watershed in Southern Sierra Nevada. This information will be valuable for sustainable water resource management in California and elsewhere. We also developed educational materials related to Hydrology and GIS for high school teachers. These materials are valuable to train the next generation of hydrologic scientists.

University of California Riverside (Jirka Šimůnek)

- The HYDRUS models are continuously being updated based on the basic research carried out by the W4188 group. The HYDRUS-1D model was downloaded more than ten thousand times in 2023, and over sixty thousand HYDRUS users from all over the world registered at the HYDRUS website. We continue supporting all these HYDRUS users from the USA and around the world at the HYDRUS website using various tools, such as Discussion forums, FAQ sections, and by continuously updating and expanding a library of HYDRUS projects. Additionally, we have added new capabilities to rigorously consider multiple new processes in the soil profiles. Finally, in 202 we have offered three short courses on using HYDRUS models in Europe, North America, and Asia/Oceania. Over 100 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 green 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.

University of California, Davis (Helen E. Dahlke)

- Development of a conditional kinetic, mobile-immobile vadose zone flow and transport model is best to estimate nitrate leaching, soil residual nitrate and nitrogen cycling processes across multiple soil textures in response to intentional flooding for groundwater recharge.
- Subsurface heterogeneity and specifically the fraction of sand present in the subsurface control the degree of preferential flow present in the vadose zone and can vary travel times by up to 38 %.
- Nitrate leaching is the dominant nitrogen loss pathways during agricultural managed aquifer recharge, while denitrification plays a lesser role and is mainly limited by substrate availability for denitrifying bacteria.
- Non-equilibrium (e.g. mobile-immobile) reactive transport HP1 models that incorporateconditional environmental factors such as temperature, soil moisture, and a proxy for oxic/anoxic conditions (percent pore-space filled) results in superior model performance representing the timing and magnitude of important biogeochemical processes when estimating cumulative NO3– leached from the shallow vadose zone.

Desert Research Institute (Markus Berli)

- 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.

Washington State University (Markus Flury and Joan Wu)

- Our results indicate that stemflow is a significant contributor to preferential flow of water in soils, and thereby controls moisture distribution in the vicinity of trees. This is an important contribution to the understanding of forest hydrology.
- We also showed how microplastics affect soil health (including soil organisms, i.e., earthworms, and soil physical properties).
- We determined critical microplastic concentrations below which no detrimental effects are expected. This information is crucial when assessing environmental plastic pollution in terrestrial systems.
- We have disseminated this information to the broader public via several podcast, newspaper interviews, and extension publications.
- Our modeling results on soil erosion in the inland Pacific Northwest shows that erosion rates have noticeably decreased from the past to the present. The decreasing trend was primarily due to the increased adoption of conservation tillage and crop rotation, as well as a decrease in the number of high-intensity precipitation events in the present climate.

University of Wyoming (Thijs Kelleners)

- Environmental monitoring data and surface-based geophysical measurements are combined with numerical modeling, parameter estimation, and uncertainty analysis to estimate subsurface structure and hydraulic properties and to predict subsurface water storage and flux at the plot,

hillslope, and catchment scales. This project is supported by NSF award 1818550 "Subsurface structure and flow regime for Rocky Mountain hillslopes with different geologies".

The University of Arizona (Markus Tuller)

- The OPtical TRApezoid Model (OPTRAM) for estimation of soil moisture based on remotely sensed transformed SWIR surface reflectance that we developed in 2017 in collaboration with Utah State University (Morteza Sadeghi and Scott Jones) has been applied globally in numerous research projects in 2023.

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

- A NASA grant proposal was funded ($2,000,000, Jones PI, Bugbee Co-I, Bingham Co-I, Apr 2023-Mar 2025) with title, "Design, Monitoring and Management Approaches for the Root-Zone in Microgravity: Phase B".
- A USU Extension Water Initiative Grant proposal was funded ($150,000, Jones PI, June 2023-May 2025) with title, "Decision-Making Tools for Crop- and Rangeland-Production using Improved Soil Moisture Algorithms".

University of Nebraska - Lincoln (Aaron Lee M. Daigh)

Impact Statement for Target Audience

- The quantification of landslide conditioning factors for North Dakota's 66,894 identified slope failures provides the foundation for future landslide risk mapping that is calibrated to its geographical regions and landscape conditions (semi-arid, continental climate, frigid and saline soils). The research will inform a broad range of stakeholders in the state for future planning of operations and land use to ensure human safety and minimize infrastructure damage.
- Irrigation management is vital for food and feed production and protecting water resources. A rich body of literature has developed on the impacts of irrigation water quality on soil salinity and crop production. Meanwhile, a separate body of literature has developed on irrigation rates and NO3-N losses in cropping systems. However, the integration of these two situations (salinity and nitrogen losses) remains largely unexplored. This work and the transfer of knowledge to producers and other stakeholders will result in improved ability for balancing irrigation and fertilizer practices to control for both soil salinity and nitrate nitrogen losses.
- Weather data and irrigation are typically submitted as regular, discrete timesteps to hydrologic models. The choice of timestep is often constrained by the availability of data. For example, weather data may only be available at hourly, daily, or monthly timescales. When submitted to a model, these data impose the assumption of uniformity over the timestep. The extent to which this assumption deviates from the real conditions may induce systematic errors. This research will inform model users and product end users on error propagation for projecting nitrate nitrogen losses due to model choice (scale) and constraints on available weather data.
- Physics-based models are commonly used to estimate deep drainage fluxes since direct quantification in field situations is generally difficult. Inputs for these models are becoming more

available due to expansion of weather mesonets and adoption of in-situ or proximal soil moisture sensing, which further promote the use of models to estimate deep drainage in the vadose zone as aquifer recharge. However, model assumptions and level of validation affect the uncertainty and sensitivity of deep drainage estimates. This research will inform model users and product end users on uncertainties and error propagation due to unconfirmed model assumptions for aquifer recharge studies and how such errors may increase with climate change.

Impact Statement for Broader Public

- The activities and results of the project were disseminated in forms that are available to audiences well beyond the target audiences. This means that other stakeholders have access to the information and can use the findings to inform them on related and connected issues around landslide conditioning, soil salinity, and nitrate losses/remediation.

Oklahoma State University (Tyson Ochsner)

- This research includes scientific and career mentoring for one PhD student. This line of work has been leveraged in a subsequent USDA NRCS research grant focused on soil climate dynamics.

Texas A&M University (Binayak P. Mohanty)

Our multi-scale process understanding, 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, climate forecasts, flood and drought prediction, groundwater recharge estimation, GHG emission, and pollution control. 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.

Texas A&M University (Briana Wyatt)

- Improved understanding of surface water resource availability in five key watersheds
- Potential for improved water management and decision making for three partner irrigation districts

New Mexico State University (Manoj K. Shukla)

- The project on “water use efficiency improvement using micro-gravity drip irrigation system. A research and demonstration experiment in Leyedecker Plant Science Center of NMSU demonstrated the potential to shift irrigation from flood to a more efficient micro-gravity drip irrigation system.

University of Florida (Ebrahim Babaeian)

- The acquired knowledge will enhance our understanding of the water dynamics and hydraulic properties of sandy soils as well as their influence on agricultural water and nutrient management and sustainability of surface and groundwater resources.
- The new data-driven modeling tools, in conjunction with ground and satellite observations, will play a crucial role in advancing hydrologic modeling, soil health in agriculture, mitigation of climate change impacts, and the security and sustainability of soil and water resources.

Louisiana State University-Agriculture Center (Xi Zhang)

- Provide local producers in Louisiana 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.
- Deliver lectures and outreach articles to growers and agricultural research stations in Louisiana on using conservation agriculture practices to improve agricultural system productivity.
- Receive support from federal funding agency and state and regional commodity boards.

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6) Zhang, X., C. Jeong, S. Dodla and S. D. Conger. Spatial variability of soil properties in agricultural fields: what does this mean for soil water and nutrients management and crop production in Louisiana. Louisiana Soybean and Grain Research and Promotion Board. Apr. 2022-Mar. 2024.
7) Jeong, C., S. Dodla, J. Wang and X. Zhang. Fertility loss via soil erosion and runoff water quality from rainfed and irrigated croplands. Louisiana Soybean and Grain Research and Promotion Board. Apr. 2021-Mar. 2024.

University of Kentucky (Ole Wendroth)

- Kentucky Small Grain Growers' Association, Project "Spatial stability of production in irrigated and non-irrigated farmers' fields" ($6,000); 2022-2023
- Kentucky Corn Growers' Association, Project "From Point to Field – Exploring Lateral Processes in the Management of Water and Nitrogen in a Farmer's Corn Field" (10,000); 2023-2024

North Carolina State University (Josh Heitman) and Iowa State University (Robert Horton)

- 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.

Virginia Tech (Ryan Stewart)

- *Improving Water Management in Pine Bark Substrates*

Rationale: Pine bark-based substrates are widely used in the United States, due to their low cost, widespread availability, and excellent aeration. Pine bark substrates also have some potential drawbacks, such as suffering from non-uniform wetting and often having poor water and nutrient retention. The wettability, water retention, and aeration characteristics of pine bark media may be improved by adjusting the particle sizes (e.g., through sieving) or by amending it with other components like peat, coir (a coconut by-product), or wood fiber products.

Response: With funding from the USDA ARS and the Horticultural Research Institute, we took a typical pine bark material (i.e., ¼"-minus), and sieved subsamples to four different size fractions: < 1 mm (< 1/25"), 1-2 mm (1/25"-1/12"), 2-4 mm (1/12"-1/6"), and 4-6 mm (1/6"-1/4"). We also blended subsamples with Sphagnum peat, coconut coir, and two wood fiber products, a disk-refined fiber and an extruded fiber. We characterized pore sizes that contributed to water movement during wetting by using tension infiltration experiments, and quantified the water retention characteristics using drainage measurements. We also measured gas diffusion rates under different water contents to evaluate if aeration characteristics were influenced by the water retention characteristics of the different substrates.

Results: The larger particle sizes (i.e., 2-4 mm and 4-6 mm) had greater porosity than the smallest (<1 mm and 1-2 mm) fractions. The amount of water that freely drained from the substrates under gravity was inversely proportional to the particle size, with the 4-6 mm fraction having the most water that drained out of the bark. Conversely, the smaller particle sizes had the most water that was retained for plant growth. Amending pine bark with other materials reduced the total porosity of the material, because the other components likely filled in pore space between bark particles. The coir, peat, and disk-refined wood fiber amendments all improved the water holding ability of the pine bark substrate, but the extruded wood fiber material did not.

Hydraulic conductivity, which is an indication of the rate at which water can enter the substrate, had an inverse relationship with particle size. The smallest-sized particles had the fastest infiltration rates, and the largest particles the slowest. This finding was contrary to expectations, and were likely because pores in the larger-sized fractions did not become fully wetted during the infiltration process. However, the smaller-sized particles also had greater water repellency at the start of the experiments. The coir-amended pine bark had higher infiltration rates than the other materials, while the fiber amendments reduced hydraulic conductivity. Therefore, the type and wettability of different amendments influence whether those materials increase or restrict infiltration rates in pine bark growing media.

These wetting behaviors also affected gas exchange. The substrates with the largest particle sizes (i.e., 2-4 and 4-6 mm) had similar oxygen exchange rates for all wetness conditions that were tested, the < 1 mm and 1-2 mm particles had significantly lower gas exchange rates when fully wetted and allowed to drain. The gas diffusion coefficient, which depicts the rate at which gases such as oxygen are exchanged, was fives times smaller when the <1 mm and 1-2 mm substrates were fully wetted and allowed to drain as compared to when they were maintained at a moderate moisture content of 60%.

In conclusion, smaller-sized pine bark substrates can be useful for infiltrating and storing water relative to larger-sized particles. Amending pine bark with coir or disk-refined fibers can also enhance water retention of pine bark. Such effects may be most pronounced in larger containers, where the upper layer of substrate often becomes excessively dry due to gravitational drainage and evaporation.

This work has been presented and published in two conference proceeding papers, one M.S. thesis. Three manuscripts are in the process of being submitted that will detail all of these experiments and findings. A summary of the work has also been released to the Horticultural Research Institute via a final project report, submitted in 2023.

- *Tree Planter Characterization and Improvement*

Rationale: Many localities implement tree pit structures within built urban hardscapes, for example in sidewalks or adjacent to other paved areas. However, concerns have been raised about the relative effectiveness of common tree pit designs, including the ability of the soil media utilized to support medium- and long-term tree growth along with their relative effectiveness at retaining nitrogen (N) and phosphorus (P) against leaching or drainage losses. In particular, primary questions have been raised regarding (1) the ability of manufactured soil media to retain and supply adequate soil moisture for tree growth due their relatively high permeability, and (2) the potential for plugging of media over time due to numerous factors including sedimentation, road salt inputs, and natural degradation of the organic components leading to settling. There is also uncertainty related to the effectiveness of under-drainage systems that are often used with tree pit designs.
Response: We partnered with Fairfax County, Virginia, on a 3-year study to characterize and improve tree pit performance. In the first project year, we collected and analyzed media samples from tree pits that represented unhealthy or dead versus healthy trees. We characterized typical growing media samples from several local vendors, and analyzed those products for their chemical and physical properties. Then we performed simulated leaching experiments using laboratory columns and larger-scale outdoor mesocosms to quantify N and P leaching dynamics through time. In the second project year, we focused our efforts on (1) a second round of paired good/bad tree planter pit sampling, (2) our long-term column leaching study, (3) development of a second generation larger column study, and (3) installation and initial monitoring of a field-scale mesocosm leaching experiment.
Results: Preliminary results from the first year indicated that some tree pit growing media has a higher-than-ideal amount of rock fragments from the topsoil component. This information has been relayed to partner entities and the Virginia Department of Environmental Quality. Our initial leaching tests indicated that fresh media can have an initial flush of carbon and phosphorus.

In the second year, a detailed analysis of 22 pairs of adjacent tree planters where relative tree growth (good/bad) differed strongly revealed a surprisingly high degree of variability in rooting zone conditions between and across sites. There were no overall consistent explanatory differences in soil properties between good/bad tree pairs; however, high soluble salts, lower extractable phosphorus, lack of suitable

soil media, compaction, strong vertical variability, inclusions of non-soil materials and poor planting practices appeared to influence tree health between many of the studied pairs. Continued evaluation of our initial leaching column studies reinforced our initial concerns regarding the short-term potential for actual net release of nitrogen and phosphorus forms from freshly placed media. However, initial results from the field-scale mesocosms indicate that actual nitrogen and phosphorus release may be lower under natural conditions (i.e., with vegetation & ambient rainfall).

University of Delaware (Yan Jin)

- The 2021 review paper (Franklin et al., SBB) was selected by the journal editors as one of three exemplary articles in terms of their provided insight in recognition of World Soil Day
- Better understanding of biophysical processes in relation to soil structure can be used in efforts to maintain healthy soil and execute best management practices
- "Organo-mineral associations and size-fractionated colloidal organic carbon dynamics in a redox-controlled wetland" paper was selected as "Editors Choice" for the month October, 2023 by the Geoderma jounral editor in chief.
- Improved understanding of how soil vertical textural contrast (a case of heterogeneity) affects saltwater evaporation through laboratory experiments
- Demonstrated the critical role of Plant Growth-Promoting Rhizobacteria (PGPR) in affecting soil evaporation under saline conditions
- Improved understanding of how saltwater intrusion may impact nutrient release in coastal regions endangered by sea level rise

University of Wisconsin-Madison (Jingyi Huang)

- We organized a series of outreach events on 2023 Ag Discovery Day at Wisconsin State Fair Park, Juneteenth Celebration of Science, 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
- We co-organized the Global Conference of Sandy Soils in Madison, Wisconsin during summer 2023. The conference consisted of 2.5 days of presentations and discussions, and a 1-day field trip to the Wisconsin Central Sands Plain. There were 60 participants from 17 countries, including Dr Richard Heck, Chair of Division 1, and Dr Takashi Kosaki, past President of the International Union of Soil Sciences (IUSS). The conference focuses on the following six topics: Distribution and formation; Monitoring, mapping and sensors; Soil carbon; Nutrient management and soil health; Soil and water conservation, and Environmental issues.

University of Minnesota (John L. Nieber)

- We have shown that it is possible to improve streamflow forecasting using a regionally calibrated machine learning model. We have also shown that such a model can effectively simulate streamflow in test watersheds even when only a very limited amount of calibration data are available for the watershed.

- The knowledge-guided machine learning models being developed will be useful to river flow forecasters to improve their ability to forecast floods and droughts. This will be useful in terms of safety/security, and monetary savings.

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Book Chapters

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4) He, H., W. Zou, S.B. Jones, D.A. Robinson, R. Horton, M. Dyck, V. Filipović, K. Noborio, K. Bristow, Y. Gong, W. Sheng, Q. Wu, H. Feng and Y. Liu. 2023. Critical review of the models used to determine soil water content using TDR-measured apparent permittivity. Advances in Agronomy. Vol. 182. pp 169-219. Academic Press. https://doi.org/10.1016/bs.agron.2023.06.004
5) Mohanty, B.P., V. Sehgal, and D. Mishra. Monitoring Climate, Water, and Moisture Resources in Rangelands with the Aid of Remote Sensing and Emerging Novel Technologies in Remote Sensing of Rangelands - Monitoring the Anthropocene, Editors: Opha Pauline Dube and John Isaac Molefe, (Invited) The 2023 Global Sustainable Development Report (GSDR) Series of the United Nations, in Revision.
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12) Oster, J.D. and A.L.M. Daigh. 2023. Use of models to assess salinity and water stress for irrigated corn production. Chapter 7, In DeSutter, T. and Clay, D. (Eds.) Managing Dryland Soil Salinity and Sodicity. Wiley. In Press.

Reports and Popular Press Articles

1) Fidelibus, M. and H.E. Dahlke. 2023. Reducing Nitrate Contamination of Groundwater Associated with Flood-Managed Aquifer Recharge (Flood-MAR). Practical Winery & Vineyard content – Wine Business Monthly Op-ed. https://www.winebusiness.com/wbm/?go=getArticleSignIn&dataId=279365

Proceedings Papers and Conference Abstracts

1) Ajmera, B., A.L.M. Daigh, and K.R. Upadhaya. 2023. Statistical study of the geology, topography, and pore fluid salinity controls on the large slope failures in North Dakota. Geo-Congress 2023. March 26-29th. Los Angeles, California.
2) Biesek, B., A. Szymkiewicz, and J. Šimůnek, Modeling PFAS movement through vadose zone with root water uptake and non-uniform organic carbon distribution, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
3) Biesek, B., A. Szymkiewicz, J. Šimůnek, A. Gumuła-Kawęcka, and B. Jaworska-Szulc, Influence of plant water uptake and organic carbon distribution on PFAS movement through the vadose zone, The 50th Congress of the International Association of Hydrogeologists, 17-22 September, 2023, Cape Town, South Africa, 2023.
4) Brunetti, G., J. Šimůnek, and R. Kodešová, Re-greening HYDRUS; Towards a unified physically-based soil-plant model, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
5) Brunetti, G., J. Šimůnek, D. Jacques, T. Zhou, and M. Šejna, Recent developments and applications of the HYDRUS model for the numerical analysis of processes in the vadose zone, Le Giornate Dell'Idrologia della Sociata Idrologica Italiana 2023, Matera, Italy, September 13-15, 2023.
6) Brunetti, G., J. Šimůnek, T. Wöhling, and C. Stumpp, Pitfalls and opportunities in the use of Markov-Chain Monte Carlo Ensemble Samplers for vadose zone model calibration, EGU23-11129, Section HS8.1.7 – Parameter Inference, Uncertainty Quantification, Error Modelling and Model Choice in (Sub)surface Hydrology, EGU General Assembly 2023, Vienna, Austria, April 24-28, 2023.
7) Brunetti, G., R. Kodešová, H. Švecová, M. Fér, A. Nikodem, A. Klement, R. Grabic, and J. Šimůnek, Using HYDRUS for simulating behaviour of six pharmaceuticals in soil columns with green pea plants, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.

8) Cai., S., Chen, K.Y, Kachhadiya, J., Joseph A., Huang, J. Evaluation of a Potentiometric Nitrate Sensor for Monitoring Real-time Nitrate Concentration in Soil. 2023 American Society of Agricultural and Biological Engineers Annual International Meeting, July 9-12, 2023, Omaha, NE.
9) Cai., S., Chen, K.Y, Kachhadiya, J., Joseph A., Huang, J. Fabrication and Evaluation of a Potentiometric Nitrate Sensor for Monitoring Real-time Nitrate Concentration in Soil. American Geophysical Union Fall Meeting, December 11-15, 2023, San Francisco, CA.
10) Chen, L., J. Šimůnek, S. A. Bradford, H. Ajami, and M. B. Meles, A novel computationally efficient hydrologic modeling framework to simulate water, solute, and sediment transport at the hillslope scale, Geological Society of America, October 15-18, 2023, Pittsburg, Pennsylvania, 2023.
11) Dahlke, H. E., T. Zhou, E. Levintal, G. Brunetti, S. Jordan, T. Harter, I. Kisekka, and J. Šimůnek, The impact of vadose zone heterogeneity on flow and contaminant transport during agricultural managed aquifer recharge: Findings from an experimental and modeling study, H040 - Climate proofing our water supply through upscaling managed aquifer recharge, ID#1360804, AGU Annual Meeting, San Francisco, California, December 11-15, 2023.
12) Dahlke, H.E. 2023. Agricultural Managed Aquifer Recharge (Ag-MAR) – A Method for Sustainable Groundwater Management. Invited webinar talk for the Water Resources Research Center at the University of Arizona, Invited by Sharon Megdal, September 7, 2023
13) Dahlke, H.E. 2023. Estimating the impact of vadose zone heterogeneity on agricultural managed aquifer recharge: A combined experimental and modeling study. Oral presentation at the 6th Western Groundwater Congress, Burbank, CA, September 14th, 2023.
14) Dahlke, H.E. Agricultural managed aquifer recharge: Plant response, hydrologic, and geochemical processes in almonds. Invited talk at the California Farm Bureau Nut Trees Meeting in Sacramento, CA on March 27, 2023. 35 people attending.
15) Dahlke, H.E. Agricultural managed aquifer recharge: Plant response, hydrologic, and geochemical processes. Invited talk at the Madera County Almond Day, Madera, CA on March 23, 2023. 70 people attending.
16) Dahlke, H.E. Flood-MAR: where are we in 2023? Invited talk at the Flood-MAR Network workshop on March 22, 2023. Online presentation. 125 attending
17) Dahlke, H.E. Managed Aquifer Recharge as a Tool to Enhance Sustainable Groundwater Management in California. Invited talk at the California Extreme Precipitation Symposium in Davis, CA on June 27, 2023. 300 attending.
18) Dahlke, H.E. Nitrate leaching under Ag-MAR. Oral presentation given at the California Water and Environmental Modeling Forum, Folsom, CA on April 18, 2023.

19) Dahlke, H.E. Nitrogen fate during agricultural managed aquifer recharge: Linking plant response, hydrologic, and geochemical processes. Invited talk at the Dixon and Solano RCDs Groundwater workshop on January 24, 2023. 50 people attending.
20) Dahlke, H.E. On-farm recharge to achieve large scale intentional recharge -achievements and challenges. Invited talk at the Associations of California Water Agencies Agricultural Committee Meeting on February 15, 2023. 55 people attending.
21) Dahlke, H.E. Quantifying the environmental effects of implementing managed agricultural aquifer recharge in agricultural production systems. 77th Annual meeting of the Soil and Water Conservation Society, July 31-August 3, 2022, Denver, CO.
22) Dahlke, H.E. Storing More Water Through Intentional Groundwater Recharge. Invited talk at the UC ANR statewide Conference, Fresno, CA, April 25, 2023; 88 attending.
23) Daigh, A.L.M. and J. Cronk. 2023. Timestep effects on simulated water and nitrogen fluxes in a virtual sprinkler-irrigation setting. Soil Physics across Scales: Challenges and Opportunities in Measurement and Modelling session, Soil Physics and Hydrology Division, Soil Science Society of America. In Annual Meeting Abstracts. ASA-CSSA-ASA Madison, WI. October 31st, 2023.
24) Daigh, A.L.M., J. Oster, S. Taghvaeian, and B. Askri. 2023. Sprinkler-irrigation waters on soil salinity, nitrogen fertilizer, and crop water use: Virtual experiments in HYDRUS. Applications of Agricultural Systems Models to Address Emerging Issues and Climate Resilience Poster Session. Model Applications in Field Research Community. Climatology and Modeling Section. American Society of Agronomy. In Annual Meeting Abstracts. ASA-CSSA-ASA Madison, WI. October 30th, 2023.
25) Daigh, A.L.M.. 2023. Deep drainage uncertainty and sensitivity to model assumptions, level of validation, and uniformity of water inputs: Virtual experiments in HYDRUS. Soil Physics and Hydrology Division, Soil Science Society of America. In Annual Meeting Abstracts. ASA-CSSA-ASA Madison, WI. November 1st, 2023.
26) Daroub, S., H. Gollany, A. Daigh, G. Jha, C. Oladoye, C. Olson, H. van Miegroet, C. Williams, S. Chapman, B. Jacques, R. Owen, R. Turco, and S. Ying. 2023. Assessment and recommendation for SSSA Diversity, Results from S529 Inclusivity Assessment Committee. Diversity Showcase. In Annual Meeting Abstracts. ASA-CSSA-ASA Madison, WI. October 29th - November 1st, 2023.
27) Durner, W., J. Šimůnek, and S. Iden, Coupled hydrothermal modelling of subsurface heating in the vicinity of high-power power cables under natural conditions, EGU23-12451, Section HS8.3.4: Flow and transport in the vadose zone – Experimental and modeling approaches for characterizing processes in a heterogenous soil-plant system, EGU General Assembly 2023, Vienna, Austria, April 24-28, 2023.
28) Franklin, S., B. Vasilas, and Y. Jin. Impacts of soil structural heterogeneity on biogeochemical processes. SSSA Annual Meeting, 2023, St. Louis, MI
29) Freedman, Z., Zhang, Y., Ghimire, S., Huang, J., Whitman, T., Majumder, E., Andrews, J., Hartemink, A.E. MIR spectroscopy can predict biogeochemically relevant soil

microbial properties at the continental scale. American Geophysical Union Fall Meeting, December 11-15, 2023, San Francisco, CA.

30) Gumuła-Kawęcka, A., B. Jaworska-Szulc, A. Szymkiewicz, W. Gorczewska-Langner, R. Angulo-Jaramillo, and J. Šimůnek, Influence of long-term climate variability on groundwater table in shallow outwash aquifers in northern Poland, The 50th Congress of the International Association of Hydrogeologists, 17-22 September, 2023, Cape Town, South Africa, 2023.
31) Gumuła-Kawęcka, A., B. Jaworska-Szulc, A. Szymkiewicz, W. Gorczewska-Langner, R. Angulo-Jaramillo, and J. Šimůnek, Using the HYDRUS-1D model to simulate climate change impact on vadose zone and shallow groundwater, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
32) Hu, J., Huang, J. Improved Soil Hydraulic Configuration in CLM5 Reduces Transpiration Uncertainty at Selected NEON Sites. American Geophysical Union Fall Meeting, December 11-15, 2023, San Francisco, CA.
33) Huang, J. 2023. Data-model integration for land surface process modeling and monitoring. Invited Oral presentation at the USDA Hatch Multi-state W-4188 Annual Meeting, January 3-4, 2023, Las Vegas, NV.
34) Huang, J. 2023. Sensor-informed soil water, nitrate, and greenhouse gas monitoring and management for climate-smart agriculture. 2023 National Cooperative Soil Survey (NCSS) conference, July 9-13, Bismarck, ND.
35) Huang, J., Hartemink, A.E. 2023. Soil and environmental issues in sandy soils. Global Conference of Sandy Soils, June 4-8, 2023, Madison, WI.
36) Huang, J., Hartemink, A.E., Arriaga, F., Chaney, N.W. 2023. High-Resolution Soil Moisture Mapping Using Sentinel-1 and Moisture Probes in Cultivated Sands. Global Conference of Sandy Soils, June 4-8, 2023, Madison, WI.
37) Huang, J., Peng, Y., Yang, Z., Zhang, Z., 2023. Machine Learning Based High-Resolution Soil Moisture (ML-HRSM) Across the Continental US. American Meteorological Society Annual Meeting, January 8-12, 2023, Denver, CO.
38) Iden, S., J. Šimůnek, and W. Durner, Coupled hydrothermal modelling of subsurface heating near power cables under atmospheric boundary conditions, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
39) Jacques, D., J. Šimůnek, H. Meeussen, E. Laloy, Recent progress in the development of the HPx framework for reactive transport calculations, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.

40) Jarecke, K.M.*, R.M. Keen, V. Moreno, M. Dumont, J.B. Nippert, S.A. Billings, A.N. Flores, K. Singha, K. Sadayappan, B. Li, D.R. Hirmas, H. Ajami, L. Li, X. Zhang and P.L. Sullivan. Impacts of woody encroachment on soil hydrology: insights from root distribution, soil moisture time series, and electrical resistivity imaging. AGU Fall Meeting, San Francisco, CA. Dec. 11-15, 2023.
41) Jarecke, K.M.*, V. Moreno, R.M. Keen, K. Sadayappan, B. Li, D.R. Hirmas, K. Singha, J.B. Nippert, L. Li, J.C. Pachón, H. Ajami, S.A. Billings, A.N. Flores, X. Zhang and P.L. Sullivan. Illuminating soil hydrologic processes in a woody-encroached tallgrass prairie using electrical resistivity imaging and soil moisture data. Interagency Conference on Research in the Watersheds, Corvallis, OR. Jun. 5-8, 2023.
42) Jeong, C.*, H. Jeon and X. Zhang. Recycling tailwater using agricultural return-flows to improve irrigation water quantity and quality in Louisiana. Annual Louisiana Water Conference. Baton Rouge, LA. Aug. 2-3, 2023.
43) Joshi, S., Afsar, M., Yan, J., Gu, C., Przywara D., Fishel, M., Jin, Y., Sparks, D.Salinity and redox oscillation induced phosphorus cycling in tidal salt marsh sediments". SSSA Annual Meeting, 2023, St. Louis, MI
44) Khan, A. G., Imran, M., Khan, A. U. H., Fares, A., Šimůnek, J., Ul-Haq, T., ... & Ali, S. (2021). Performance of spring and summer-sown maize under different irrigation strategies in Pakistan. Sustainability, 13(5), 2757. https://e1sustainability.theresearchcatalyst.com/.
45) Kodešová, R., G. Brunetti, H. Švecová, A. Klement, M. Fér, A. Nikodem, R. Grabic, and J. Šimůnek, Modelování transportu a transformace miropolutatntů v systému půda rostlina (Modeling the transport and transformation of micropollutants in the soil-plant system), Conference "Hydrology of Small Catchments 2023" (Hydrologie malého povodí 2023), 30.5.–1.6. 2023, Institute for Hydrodynamics, Czech Academy of Sciences, Prague, 2023.
46) Lawal, M., A. Mittelstet, T. Gilmore, D. Snow, and A. Daigh. 2023. Multi-model assessment of nitrate leaching from manure and commercial fertilizer application in East Central Nebraska. Water for Food Research Forum, April 13th, 2023. Lincoln, Nebraska
47) Lazarovitch, N., I. Kisekka, T. E. Oker, G. Brunetti, T. Wöhling, L. Xianyue, L. Yong, T. H. Skaggs, A. Furman, S. Sasidharan, I. Raij-Hoffman, and J. Šimůnek, Modeling of Irrigation and Related Processes with HYDRUS, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
48) Meles, M. B., L. Chen, C. Unkrich, H. Ajami, S. A. Bradford, and J. Šimůnek, Scaling up a hillslope scale coupled surface-subsurface hydrological model to watershed scale: A computationally efficient modeling framework, ID#1421464, AGU Annual Meeting, San Francisco, California, December 11-15, 2023.
49) Meles, M. B., L. Chen, H. Ajami, S. A. Bradford, and J. Šimůnek, Scaling up a hillslope scale coupled surface-subsurface hydrological model to watershed scale: A

computationally efficient modeling framework, Geological Society of America, 15-18 October, 2023, Pittsburg, Pennsylvania, 2023.

50) Nasta, P., T. Zhou, C. Stumpp, J. Šimůnek, and N. Romano, Assessing the temporal origin of root water uptake and drainage water using a virtual tracer experiment, EGU23-4203, Section HS10.4 – Stable isotopes to study water and nutrient dynamics in the soil-plant-atmosphere continuum, EGU General Assembly 2023, Vienna, Austria, April 24-28, 2023.
51) Nelson, R., A.L.M. Daigh, and E.E. McGinnis. 2023. Parking lot deicing rates reduce plant quality of ornamental grasses: A greenhouse evaluation. Northern Region of the American Society for Horticultural Science Annual Meeting. Virtual. January 5-6th, 2023.
52) Pachon, J.*, D. Hirmas, H. Ajami, P. Sullivan, S. Billings, K. Jarecke, M. Sena, X. Zhang, L. Li, K. Singha, J. Nippert, A. Flores, X. Cao and A. Nemes. Incorporating structural macropores into dual porosity water retention pedotransfer functions. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.
53) Pachon, J.*, D. Hirmas, H. Ajami, P. Sullivan, S. Billings, M. Sena, X. Zhang, L. Li, K. Singha, J. Nippert, A. Flores and X. Cao. Visible to the eye, now in the model: parameterizing dual porosity water retention functions in structured soils. EGU General Assembly, Vienna, Austria. Apr. 23-28, 2023.
54) Pawłowicz, M., B. Baliś, A. Szymkiewicz, and J. Šimůnek, Development of a coupling interface for Hydrus-1D and MODFLOW 2005, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences, Prague, Czech Republic, 2023.
55) Šimůnek, J., G. Brunetti, D. Jacques, T. Zhou, and M. Šejna, HYDRUS and its Specialized Modules (Version 5) for Numerical Modeling of Vadose Zone Processes, ID: 153342, SSSA Annual Meeting 2023, San Louis, Missouri, October 29-November 1, 2023.
56) Šimůnek, J., G. Brunetti, D. Jacques, T. Zhou, and M. Šejna, Numerical Modeling of Vadose Zone Processes using Version 5 of HYDRUS and its Specialized Modules, EGU23-10247, Section HS8.3.4: Flow and transport in the vadose zone – Experimental and modeling approaches for characterizing processes in a heterogenous soil-plant system, EGU General Assembly 2023, Vienna, Austria, April 24-28, 2023.
57) Šimůnek, J., M. Th. van Genuchten, G. Brunetti, D. Jacques, and M. Šejna, Recent developments and applications of the HYDRUS software packages, Book of Abstracts of the 6th International Conference "HYDRUS Software Applications to Subsurface Flow and Contaminant Transport Problems," April 20-21, 2023, ISBN 978-80-213-3264-5, Czech University of Life Sciences Prague, Czech Republic, 2023
58) Stevens, C., Huang, J. Post-wildfire land surface emissivity (8-14 μm) measured with an unmanned aerial vehicle. American Geophysical Union Fall Meeting, December 11-15, 2023, San Francisco, CA.
59) Stewart, R. D. 2024. Gold standards for substrate physico-chemical characterization (invited). Acta Horticulturae. International Society for Horticultural Sciences (in press).

60) Sullivan, P. *, and the SitS, FRES, and CZCN Teams. How do roots restructure water and carbon dynamics in the critical zone? EGU General Assembly, Vienna, Austria. Apr. 23-28, 2023.
61) Sullivan, P.L.*, L. Bixby, K.M. Jarecke, R.M. Keen, L. Souza, X. Zhang, H.R. Barnard, A.N. Flores, M.F. Kirk, J.B. Nippert, V. Moreno, K. Sadayappan, A. Guthrie, E. Hauser, H. Ajami, S.A. Billings, D.R. Hirmas, L. Li and K. Singha. Constraining the belowground ecohydrologic consequences of land cover change. AGU Fall Meeting, San Francisco, CA. Dec. 11-15, 2023.
62) Wang, Z.*, D. Timlin, R. Thapa, D.H. Fleisher, W. Sun, S. Beegum, Y. Lu, S.B. Mirsky, C. Reberg-Horton, X. Zhang, V. Reddy, R. Horton and K. Tully. Modeling the dynamics of the cover crop growth and residue decomposition in a cereal rye-residue mulch management strategy during winter fallow periods. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.
63) Wendroth, O.*, Y. Yang, L. Ma, J. Reyes, X. Zhang, L. Liang, C.A. Knott, C.D. Lee, R.J. Walton and M.A. Ilgun. Opportunities for soil physics to contribute to understanding and managing soils. ASA-CSSA-SSSA Annual Meeting, St. Louis, MO. Oct. 29-Nov. 1, 2023.
64) Wolcott, C.C., J.S. Owen Jr., and R.D. Stewart. 2024. Quantifying functional pore sizes in pine bark growing media. Acta Horticulturae. International Society for Horticultural Sciences (in press).
65) Yan, J., W. Zheng, Y. Jin. Effects of plant growth-promoting rhizobacteria (PGPR) on saltwater evaporation: A case study using Bacillus Subtilis". SSSA Annual Meeting, 2023, St. Louis, MI
66) Yan, J., W. Zheng, Y. Jin. Compensating for high evaporation: Revisiting the role of vertical textural contrast in saltwater evaporation. SSSA Annual Meeting, 2023, St. Louis, MI
67) Yang, Z., Willis, P., Huang, J., Zhang, Z. Identifying Early Season Prevented Planting Fields Using Machine Learning Based High Resolution Soil Moisture (ML-HRSM). American Geophysical Union Fall Meeting, December 11-15, 2023, San Francisco, CA.
68) Zhou, T., E. Levintal, G. Brunetti, S. Jordan, T. Harter, I. Kisekka, J. Šimůnek, and H. E. Dahlke, Estimating the impact of vadose zone heterogeneity on agricultural managed aquifer recharge: A combined experimental and modeling study, ID: 153666, SSSA Annual Meeting 2023, San Louis, Missouri, October 29-November 1, 2023.