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Book of Abstracts

Straddling the Upper and Lower Colorado River Basin: the Navajo Nation is in the Middle of It All
Crystal Tulley-Cordova, Navajo Nation Dept. of Water Resources

Drought and flooding conditions can concurrently exist. Recently, the Navajo Nation has experienced above-normal North American monsoon and winter precipitation. However, more than two decades of drought have challenged hydrological recovery. Other challenges for the Navajo Nation include transboundary issues associated with the management of the Colorado River Basin and how the Nation is impacted by short- and long-term proposed actions by states and the federal government. Over the last 100 years, there have been different varying levels of tribal engagement, Now, the Colorado River system has an unbalance between paper and wet water, and stakeholders are trying to create innovative management solutions to meet unprecedented challenges.

In the Courts of the Conqueror: "Arizona v. Navajo Nation"

Jason Robison, Univ. of Wyoming College of Law

Legal institutions are powerful instruments in shaping socioecological relations and facilitating colonization. That is certainly true of U.S. Supreme Court jurisprudence at the confluence of Western water law and federal Indian law. *Arizona v. Navajo Nation* is a testament. Currently pending in the U.S. Supreme Court, this case involves one "tributary" line of historic decisions on Western water, including *Winters v. United States* (1908) recognizing Indian reserved rights for the first time in U.S. history and *Arizona v. California* (1963) affirming *Winters*'s application in the Colorado River Basin. Fleshed out in another "tributary" line of cases, *Arizona v. Navajo Nation* also revolves around a legal construct that predates the U.S. Constitution: the trust relationship between the federal government and tribal sovereigns, including water-related fiduciary duties owed by the former to the latter. This plenary address will explore *Arizona v. Navajo Nation*, the confluence where it is situated, and its relevance to contemporaneous climate change-driven policy developments along the Colorado River.

Climate Change Impacts on Watershed Hydrology

David DeWalle, Penn State University, Warren Hall Medal Recipient

Environmental monitoring and modeling are beginning to show how climate change and global warming may be affecting watershed hydrology. Warming can directly affect hydrologic processes by increasing melt rates of glaciers and seasonal subalpine snowpacks, by converting potential snowfall to rain, and by increasing evaporation from global landscapes and ocean surfaces. Enhanced evaporation will also add water vapor to the atmosphere which can increase precipitation downwind. Monitoring of glaciers shows gradually increasing loss rates of ice mass throughout the world which will alter timing and ultimately reduce volumes of water available to sustain streamflow or flows of fresh water into oceans. Peak April SNOTEL subalpine snowpack data for the western U.S. during 1955 to 2022 also shows declines at the majority of stations with losses up to 40-60% in water equivalent common. Reductions in peak snowpack accumulations will alter the timing of subalpine meltwater supplies for streamflow and reduce inputs from late-lying snow. Mean air temperatures across the U. S. during 1901-2021 changed at rates ranging between near zero up to +4.5 degrees F per century. Increased air temperatures in rainfall-dominated regions likely have increased watershed evaporation but the amount of added loss is unknown. Over the same 1901-2021 time period annual precipitation totals also varied regionally across the U. S. by +/- 30%. Regions with precipitation gains may see precipitation gains offsetting losses due to enhanced evaporation depending upon watershed conditions. Unfortunately, desert regions of the U. S. showed some of the greatest increases in air temperatures and greatest declines in annual precipitation, which suggests further desertification and reduced groundwater recharge can occur. Increased ocean temperatures and evaporation may also be influencing the formation of more frequent and more severe “atmospheric rivers” striking coastal regions. Ocean surface temperatures are steadily increasing and have now reached about 1 degree F above the 1972-2000 mean. It appears a new era of hydrologic/atmospheric research is critically needed to help quantify and better understand impacts of climate change and global warming on watershed hydrology in the United States and globally.

Water Scarcity Solutions in a Changing Southwestern United States

Emile Elias, USDA Southwest Climate Hub

A decade ago, the United States Department of Agriculture established a network of ten regional Climate Hubs to support farmers, ranchers, and foresters in climate adaptation and mitigation. The regional organization of the network reflects variation in both the Nation's agriculture and forestry, and variations in observed and expected climate impacts. In the West, as demand for scarce water continues to increase, so does the need for research-informed solutions to relieve pressure on water resources while sustaining agricultural, urban, and wildland uses and ecosystem health. Despite often dire water scarcity, exacerbated by increasing population and a changing climate, solutions are emerging at individual, community, and regional levels in response to these challenges. This talk will highlight three efforts to document and promote these solutions in which the Southwest Climate Hub is a key partner. The Southwest Drought Learning Network (DLN) evolved in response to the exceptional drought that persisted over the Colorado Plateau for nearly all of 2018. The DLN continues to grow, based on a model of self-formed and directed teams addressing the most pressing drought challenges. The Water Adaptation Techniques Atlas (WATA) emerged from recommendations of resource managers active in the DLN who advocated for peer-to-peer knowledge exchange. WATA continues to expand and provides both decision-relevant information and diffusion of solutions. Finally, a recent Water Research Vision offers a path to advance water research and water security over the next 30 years. Despite a western water system that typically fosters competition rather than collaboration, relationships and partnerships underpin our ability to advance water solutions and build systemic resilience in the midst of a changing climate.

The Ever-Present and Growing Threat of Flash Drought in an Accelerating Hydroclimate

Jeffrey Basara, University of Oklahoma

Not all droughts are the same. In some cases, drought rapidly intensifies at subseasonal to seasonal scales with significant impacts to agriculture and water resources along with the increased propensity for heatwaves and wildfires. Like all droughts, flash drought begins with a precipitation deficit. However, both evaporative demand and soil moisture are critical flash drought variables, and identifying and monitoring the desiccation of the terrestrial surface is key for determining flash drought development and associated impacts. During flash drought, soil moisture can play two critical roles: (1) drought enhancement via dry soils, enhanced sensible heat flux, reduced evaporation, and enhanced vapor pressure deficit and, (2) drought resistance via moist soils that cool the surface via evaporation and decreased vapor pressure deficit. Yet, fundamental questions remain in the state of the science related to flash drought. For example, what is the overall relationship between atmospheric demand, evaporative stress, terrestrial desiccation, and precipitation in the progression of flash drought? Also, at what point during flash drought development does the environment transition from drought resistance (a negative feedback) to drought enhancement (a positive feedback) and vice versa? Finally, how will flash drought frequency and intensity evolve in a changing climate system?

Business Perspectives on Water Stewardship

Kevin O'Donnell, Global Sustainability Executive and Advisor

With sustainability having evolved from relative backwater to headline news, it is now a key strategy pillar or connecting thread for a growing number of global companies. This is being driven by concerns around business resiliency and continuity, rising consumer, stakeholder and investor pressure, the need to feed, fuel and resource a growing world population, as well as signs of continuing ecosystem decline. While climate often takes center stage in corporate sustainability approaches, other impact areas such as water, biodiversity and materials circularity are on the rise, as is appreciation for their interconnectedness. Various global operational and program examples will be shared from corporate leaders including Nike, General Mills and beyond. Further perspective will be added from an investment lens as well as on the dairy industry. A sampling of elements to be covered include: impact of globalized supply chains on water stewardship, what the 'China price' can mean for water, assessing risk plus opportunity and prioritizing work in key global watersheds, intersections between 'Lean' and 'Green', the role of emerging technology, development of market-based incentives, novel new approaches to baseline and value natural capital assets, and the rise of regeneration as an organizing principle to improve sustainability performance across impact areas, including water. With sustainability growing ever broader, deeper and more complex, no one entity has all of the answers, so partnership and innovation are increasingly critical to advancing progress. So with sustainability becoming more and more of a 'team sport', collaboration across complex and far-reaching value chains is necessary, often including brands, contract manufacturers, ingredient suppliers and processors, farmers, NGOs, the public sector, academia, communities, specialized consultants, and technology-enabled approaches to transparency, measurement, monitoring, reporting and validation. The goal is to leave the audience with a better sense on how the corporate water stewardship journey has evolved over time, what's worked well and what hasn't, key trends and the outlook ahead.

Connecting with Sea Grant to Leverage and Amplify Your Water Resources Work
Participatory session led by Karen Bareford, University of Alabama

On the ground, in theory, and in organizations, water resources encompass everything from water challenges to water research, water education, and water extension. Join the Sea Grant Network in untangling these threads to better leverage our efforts.

In 2018, the Sea Grant Network developed a 10-year water resources vision. Over the last 2 years, the network has developed a roadmap for Sea Grant water resources initiatives. The effort has helped identify where resources are currently directed and define where they need to be directed in the future. In addition, Sea Grant is improving internal communication and coordination. Moving forward, Sea Grant needs to improve communication and coordination with key partners. Help us understand your water resources efforts and priorities and discuss how we can best leverage complementary activities and facilitate dialogue and information sharing.

The session will begin with a short presentation summarizing current Sea Grant water resources efforts and future directions. A facilitated discussion will then elicit ways that the Sea Grant Network can best work with other entities to leverage complementary activities, minimize duplication of efforts, most effectively coordinate our work, and communicate needs and successes. Please join this session and contribute to a more coordinated effort to address our Nation's growing, complex water resources challenges.

Building Water Resiliency in Arizona - Panel Discussion

Organizers: Sharon B. Megdal, The University of Arizona; Vineetha Kartha, Central Arizona Water Conservation District

Moderator: Sharon B. Megdal, The University of Arizona

Panelists:

Rebecca Bernat, Arizona Water Banking Authority
Kristen Johnson, Arizona Department of Water Resources
Vineetha Kartha, Central Arizona Water Conservation District
Kathryn Sorensen, Arizona State University

The Colorado River Basin has been in a drought for 23 years. Based on tree ring studies, the period from 2000 to 2022 ranks as the driest period in the last 1,200 years. Some refer to the situation as a megadrought; others point to aridification. Due to the junior priority of more than half of its Colorado River allocation, Arizona has been preparing for shortages for decades by building resiliency within Arizona and taking steps to address reduced Colorado River flows. Collective efforts within Arizona to conserve water in Lake Mead have been instrumental in avoiding shortage through the last decade. Through the Arizona Water Banking Authority, Arizona has also been successful in storing Colorado River water underground in central and southern Arizona in order to make that water available to some of the Arizona Tribal Nations, and several municipal and industrial users during times of shortage. With the increased likelihood of continuing drought and additional shortages, Arizona is looking to build on its strong water management principles through additional conservation, innovative efficiency measures, and augmentation. However, actions are needed not only for users of Colorado River water. Groundwater is the source of over 40% of Arizona water uses, with some communities 100% dependent on groundwater. Importantly, as surface water supplies diminish, some water users are shifting to the utilization of groundwater at rates that far exceed replenishment rates. This panel will provide up-to-date information on the Arizona water situation, strategies, and solutions.

SipSafe Program: Findings from Two Years of Lead Testing in Drinking Water at Child Care Facilities
Jason Barrett, Mississippi State University

Lead in drinking water has had heightened attention since the Flint Michigan crisis even though lead has been an issue for years. The EPA has passed the lead and copper rule that regulates and dictates testing for lead in drinking water systems but does not specifically address the most at-risk individuals which are youth under the age of six. This research and extension effort focuses on childcare facilities with a goal of determining best practices to reduce and/or eliminate the expose of lead in drinking water by testing for lead at each faucet within each facility. Protecting children from lead exposure plays a critical role in ensuring they develop into healthy adults. Children under the age of 6 have shown slowed growth, learning disabilities and other physical and mental impairments after prolonged exposure to environmental lead. The SipSafe Program seeks to limit children's exposure to lead via drinking water by screening water in qualifying schools and childcare facilities across Mississippi, as well as offering remediation assistance and educational materials on the dangers of lead. Mississippi State University Extension with assistance from the Mississippi State Department of Health, Mississippi Department of Education, Mississippi State Chemical Laboratory, and other cooperating partners, SipSafe has developed into a program that trains, tests, and takes action to help facilities reduce the amount of lead in their drinking water and further raise state-wide awareness of lead exposure in children. It is anticipated that data collected from these counties will be beneficial in future school and childcare drinking water screening efforts. This presentation will display and discuss the findings from two years of testing approximately 76 childcare facilities in 32 different counties throughout Mississippi.

MAppFx: Production Well Nitrates Northern Guam Lens Aquifer

Dannika Valerio and Matt Zapata, Water and Environmental Research Institute of the Western Pacific, University of Guam (N. Habana, 1st author)

Interactive web map and graphs are the now and future of hydrologic database and information transfer. An interactive online web application, MAppFx, demonstrates a map point and graph display feature. Water and Environmental Research Institute, University of Guam (WERI UOG), in 2022, collaborated with Brigham Young University to build MAppFx. The first MAppFx product features production well nitrate concentrations in Guam. The purpose is to share the information with agency partners, and anyone worldwide who is interested in obtaining the information in an easy to use and access platform. This is most useful for on demand reference and research. The product expands the interagency web map product collection in the Guam Hydrologic Survey website. The Guam Hydrologic Survey (GHS) website (guamhydrologicsurvey.uog.edu) is Guam's online repository of pertinent hydrologic information, established through Guam public laws. The website is managed by WERI, UOG, and web server service is provided by UOG, Office of Information Technology, Web Development Team. The GHS website contains interagency partnership information, the public laws, outreach services (workshops and aquifer tour), hydrologic reports (technical, journal, professional papers, and workshop presentations), maps, Interagency Web MApps (new interactive web map application), borehole and production well chloride database, and an interactive map to the chloride and borehole databases. With the established website and new online interactive interface technology available, GHS Information Management Team are now inclined to pursue the expansion of hydrologic web products and field survey database. The ever-growing GHS website product is already a true testament to interagency collaboration, a great means of hydrologic information dissemination, and scientific information source for aquifer management.

Flood Management for Private Wells: Utilizing QMRA and a Survey to Understand Well User Health Risks and Perceptions after Hurricane Harvey

Anna Gitter, The University of Texas Health Science Center at Houston School of Public Health (D. Boellstorff, K. Mena, D. Gholson, K. Pieper, C. Chavarria, T. Gentry)

Flooding of private well systems and well water contamination continues to be a significant public health concern. Hurricane Harvey resulted in nearly 60 inches of rainfall, flooding not only Houston, Texas, but surrounding counties and communities. In the weeks following the hurricane, a well water sampling campaign to test private wells for fecal indicator bacteria in counties impacted by flooding was initiated. *Escherichia coli* concentrations measured in private wells were used in a quantitative microbial risk assessment (QMRA) to estimate the human health risks associated with both drinking water and indirect ingestion exposure scenarios. Derived reference pathogen doses indicated that for drinking water exposure, norovirus and *Cryptosporidium* were associated with the greatest health risks for gastrointestinal infections, exceeding the U.S. Environmental Protection Agency modified daily risk threshold of 1×10^{-6}. Showering, bathing, and food/dish washing were also identified to be exposure pathways of health concern. In addition to conducting the QMRA, a follow-up survey was developed and distributed to private well users three years after Hurricane Harvey. The aim of the survey was to evaluate well user perceptions and well stewardship practices following a natural disaster event. Generally, well users perceived their well water to be safe, regardless of education, income, or county of residence. Nearly 45% of well users participating in the survey also reported disinfecting their well system and testing their well water since Hurricane Harvey. Both QMRA and surveys can be utilized to evaluate the public health concerns affecting well users experiencing natural disasters. Information gathered through these approaches can provide scientifically and community supported guidance for well water practices and management. Additionally, as coastal communities continue to experience hurricanes and floods, developing guidance that can mitigate health risks and assist well users in managing their wells is critical.

Characterization of the Fate and Transport of Salts in Colorado River Basin using Machine Learning Approaches

Mohamed Fawzy Mahmoud, Colorado State University (M. Arabi)

Water salinity is one of the most used indices for assessing water quality. Salinity substantially influences water users in the Colorado River Basin, affecting agricultural, municipal, and industrial sectors and costing the United States around $300 million per year in economic losses. This study used a surrogate modeling approach using machine learning to characterize average annual salts levels in surface water at any point in the Colorado river basin. Model inputs are based on available hydrogeological and meteorological data. Several machine learning algorithms were used in this study, such as Random Forest (RF), Deep Neural Network (DNN), and Long Short-Term Memory Networks (LSTM). Twenty years of observations for 103 different watersheds in the Colorado river basin were randomly divided into 75% as model training data and 25% as testing data for validating the models. The study considered nineteen input parameters that were reduced to eight variables based on the amount of multicollinearity in regression analysis. Variables included as modeling inputs are average watershed soil electrical conductivity (EC), total wastewater treatment facilities (WWTF) discharge rate, watershed area, annual average river discharge, minimum annual vapor pressure deficit, and average annual precipitation. After training the models, the prediction ability of each model was assessed using statistical criteria and the testing data. The best-performing model was applied to a set of known input variables to map surface water salinity over the Colorado River Basin on the HUC 8 scale. Model analysis showed that the soil EC is the most crucial component influencing surface water salinity in the basin, followed by the discharge of the wastewater treatment facilities in the watershed. The results underline the performance validity and applicability of machine learning approaches for modeling salt levels at various locations along the Colorado River and its tributaries.

The Value of Forests in Providing Drinking Water: A Natural Capital Approach

Travis Warziniack, USDA Forest Service

This paper focuses on the value of forests for providing safe clean drinking water. We develop methods for constructing asset accounts for ecosystem services from forests consistent with standards in the UN System of Environmental-Economic Accounting (SEEA). We develop accounts for ecosystem extent, ecosystem condition, and ecosystem services and project change in forests based on the EPA's land use projections associated with climate and socioeconomic change (ICLUS). We then measure the economic impacts from forest loss in the United States on the provision of drinking water. This work overcomes past data limitations by paring recently developed US ecosystem accounts with long-term plot-level data on forest ecosystem services. Building on the growing natural capital accounting literature, we formulate regional natural capital accounts across national forests using USFS Forest Inventory and Analysis (FIA) data and examine the value of forests for providing water supplies.

The Effects of Extreme Weather on Interconnected Agricultural and Environmental Systems
Steven Buck, University of Kentucky/Western Water Network (M. Inam)

In this presentation we will consider two questions: (i) Which types of extreme weather patterns matter most in terms of frequency and magnitude of effects on interconnected agricultural and environmental systems, and (ii) How is agricultural nutrient run-off into waterways affected by the frequency, duration, and severity of drought or rainfall intensity? We will draw upon data and empirically-based case studies from the Midwest and Western United States to support our discussion.

New Strategies for Managing Irrigation Water Depletion
Kevin Wagner, Oklahoma State University

Irrigated cropland is extremely important to global food security. Although it occupies only ~16% of the total agricultural area worldwide, irrigated cropland consumes ~90% of global freshwater and supplies ~40% of the total agricultural yield globally.

However, declines in freshwater availability is a growing threat. In the U.S., major challenges have befallen the Ogallala Aquifer, Central Valley Aquifer, Colorado River, and Mississippi Alluvium Aquifer, just to name a few. Groundwater depletion in the Ogallala and California Central Valley aquifers account for ~50% of groundwater depletion in the U.S. Flow of the Colorado River has decreased almost 20% compared to its 20th century average threatening not only dependent cities, but also food production. Approximately 70% of the Colorado River's water is used for irrigation, supporting the production of 90% of the nation's winter vegetables. Even in the high rainfall southeastern U.S., depletion of the Mississippi River Valley alluvial aquifer, which supplies over 90% of irrigation water in that region, is causing major concern.

How do we adaptively manage these declines and increasing pressures? What is the effectiveness of current technologies and approaches, and what role can they play in helping adapt to water resource declines? How do we prolong, sustain, or restore freshwater resources or better utilize them along with marginal quality water? When use of existing and alternative water sources is not possible and depletion occurs, how do we best support conversion to rainfed systems? These are just a few questions that researchers, water managers, producers, and decision makers alike are grappling with and will be the focus of this track.

This track will examine new technologies, cropping system management practices, regenerative practices, decision support tools, producer and public perception insights, education approaches, and incentives and policies to sustain food production, rural communities, and ecosystem services. In particular, research advances from the Ogallala Aquifer Program, National Center for Alluvial Aquifer Research, Ogallala Water CAP, Irrigation Innovation Consortium, Regenerative Agriculture SAS, and efforts in California, Arizona, and elsewhere will be presented. The expected outcome is enhanced engagement and collaboration among the researchers working to address these issues.

The Irrigators' Dilemma: What Games Teach Us About Conserving Ground Water

Brent Auvermann, Texas A&M AgriLife Research

Following the late Nobel laureate, Dr. Elinor Ostrom, we propose a game-theoretic approach to ground water governance that gives us access to insights that may not be obvious from general equilibrium models or other standard, black-box, analytical approaches. We show that the common-pool resource dilemma that we face in ground water governance may be framed in game-theoretic terms, and the simulation behavior of a game-theoretic model replicates observed behaviors like the tragedy of the commons. The Ogallala Aquifer is a common-pool resource that is undergoing yet another manifestation of that tragedy, driven in part by Jevons' Paradox, which suggests strongly that the public research portfolio directed at conserving the Ogallala has been poorly balanced. The modest contributions that technology advances can make to extending the aquifer's useful life will be most fully realized in a larger context of innovations in cooperative resource management, innovations that will require rethinking parochial assumptions about resource ownership, property rights, land use preferences, and the time scales that define our planning horizons and economic forecasts. We also describe how recent developments in the application of cooperative game theory can provide conceptual support for voluntary irrigation associations that take bold, experimental steps toward self-organization.

The Effects of Producer-initiated Groundwater Conservation on the Hydrology of the Ogallala Aquifer in Northwest Kansas

Bridget Guerrero, West Texas A&M University (B. Golden)

Groundwater consumption rates in the southern portion of the Ogallala Aquifer have raised concerns about the long-term feasibility of irrigated agriculture. The amount of water pumped from the Ogallala Aquifer needs to be reduced in order to extend the economic life of the aquifer and maintain the economic base of the region, which is largely agricultural. Monitoring the Sheridan #6 Local Enhanced Management Area (LEMA) has allowed the observation of producer innovation when faced with water restrictions. The LEMA initially began in December of 2012 and has since been extended and expanded to all of GMD #4, increasing the overall effects of the producer-driven policy over time. Results indicate that during the study period, irrigated crop producers within the boundary of the LEMA relative to outside the boundary reduced total groundwater use by 24.9% and irrigated crop acreage by 11.8%. The producer-supplied economic data implies that cash flow did not suffer, and importantly, producers are satisfied with the economic consequences, as they have maintained their water use reductions even when given the option to ease them. The stated purpose of the LEMA legislation was to reduce groundwater consumption in order to conserve the state's water supply and extend the life of the Ogallala Aquifer. While the initial purpose of this research was to measure the economic and agronomic changes, this paper adds the hydrologic response to the LEMA. It is estimated that the decline rate within the LEMA has gone from about two feet per year to about five inches per year. The addition of hydrologic impacts will help identify proximity to aquifer sustainability. The knowledge of how irrigated crop producers reacted to conservation policies in this case scenario can be helpful to producers, stakeholders, and researchers in other areas faced with diminishing supplies who are considering implementing conservation measures.

Keywords: crops, economic, hydrology, irrigation, Ogallala, water
JEL Classifications: Q10, Q12, Q18

Estimating the Impact of Groundwater Allocations on Irrigation Behavior and Energy Use: Implications for Groundwater Policy Design

Karina Schoengold, University of Nebraska (T. Mieno)

The paper examines the impact of groundwater pumping limits on groundwater and electricity use. In this paper, we ask whether the allocation limits imposed by the governing groundwater users (i.e., the local managers) have reduced water use, and as a corollary, the associated energy used for pumping groundwater. Based on existing literature, the answer to this question is ambiguous. The study uses data from multiple local groundwater management areas (GMAs) in Nebraska with non-transferable groundwater allocations, where allocations vary across GMAs and between years. The analysis compares groundwater and electricity use across the borders of GMAs. It uses spatially disaggregated data at the individual groundwater well or electricity contract level. If no farmers are constrained, then the average water and energy use on the two sides of the border should be the same. On the contrary, if at least some of the farmers are constrained by the allocation limits, average water and energy use will be lower on the side with stricter allocation limits. Results show that while some of the allocations do constrain producers, others do not. This suggests that it is possible for groundwater allocation limits to not achieve expected reductions in water use reduction. While this may be surprising, this is possible because the local authority has an incentive to not set the allocation limits strict enough. We also found that the impact is heterogeneous across a single GMA. The results imply that policy efficiency may be improved with spatially variable policies.

USDA-NIFA's Water Q&Q: A Broad-based Program Intended to Reduce the Water Footprint of Agriculture

James Dobrowolski, USDA

Although most of the world is not running out of fresh water, supplies are stretched to meet the demands of growing populations, increased industrial development, agricultural production, and ecosystem and wildlife protection. Future shortages will be fueled by increased demands, unsustainable withdrawal rates, difficulty in finding new supplies, pollution, and source water contamination, and changing climatic and precipitation patterns. Scientists must now think about the role of water at the intersection of food, energy, manufacturing, national security, environment, and communities. Water plays key roles in 1) directing societal needs and water requirements–to satisfy demands for food, energy, and goods; 2) environmental preconditions–hydroclimate, rainfall variability, soil permeability and water-holding capacity, river runoff, groundwater flow, etc.; 3) coping ability–avoiding water-related environmental hazards (e.g., floods, droughts, disease vectors, environmental conflicts, etc.) while minimizing the side-effects of unavoidable landscape manipulations needed to meet societal needs. A fundamental pitfall exists in outdated perceptions of water functions that are severely underestimated. Consequently, water is often seen as a technical issue of supply and sanitation, dam building, and irrigation development. Crop production is focused on climate, soils, and nutrients, while water exists as a component of irrigation systems. Land use is seen as allocating space in a basically two-dimensional plane without attention to subsurface water sources or conditions. Also, ecosystem theory was developed in temperate zones stressing energy and nutrients. Since water was plenty, there was no need to focus attention on limiting its use. Wise water management will require research that: 1) integrates and emphasizes fundamental linkages between water, land use, and ecosystem health; 2) understands the necessary superstructures needed to make different actions possible (legislation, administration, financing); 3) to get necessary societal acceptance (education, public participation in decision making, etc.); and 4) to make it happen (incentives, sanctions).

It's All Over but the Drying: Transitioning Land-use Paradigms in the Southern Ogallala Region

Edward Rhodes, Texas Water Resources Institute, Texas A&M AgriLife Research (H. Perotto-Baldivieso, E. Tanner, J. Angerer, W. Fox)

The Ogallala Aquifer is the largest freshwater aquifer in North America, supplying irrigation water to one of the most agriculturally productive regions in the world. In the Southern High Plains, natural recharge of the aquifer is low to nonexistent. While improvements in technology and crop genetics have increased overall water use efficiency, the Ogallala is still a diminishing resource. It is estimated that much of the Ogallala under the Southern High Plains will be depleted or nearing depletion by 2100. Coupled with this trend is the fact that up to one-quarter of the soils in the region may not be suitable for dryland crop production. The impending drawdown of the Ogallala will have dramatic repercussions on the United States and world food supply chains. By integrating a mosaic of restorative practices such as rangeland reseeding, perennial improved pastures, and regenerative practices such as integrated crop and livestock systems, scientists and land managers have the opportunity to develop interdisciplinary research and management programs around the rehabilitation of the land, and reestablishing lost (as well as developing new) ecosystem services to this region. We propose that future research and extension efforts focus on interdisciplinary research aimed at addressing current and future potential land uses that can maximize ecosystem services and protect soil resources in a changing and uncertain climate. University curricula must adapt to prepare the next generation of land managers to this monumental task facing this region, as it is one that may become a test case for other regions globally.

Addressing the Educational Gaps: Are Water Education Programs in the Western States Creating a Sufficient Workforce for a Climate-changed Agriculture?

Organizers: Robert Heinse, Dept. of Soil and Water Systems, University of Idaho; Derek Godwin, Extension Watershed Management, Department of Biological & Ecological Engineering, Oregon State University

Panelists:
Billy Grenfell, Valmont Industries
Trevor Mecham, Valmont Industries
Holly Nelson, Chemeketa Community College
Maria Zamora Re, Oregon State University

Agriculture in the west will continue to experience challenges in climate change, water supply, technology, increasing population housing and market demand, providing water quality for expanded beneficial uses, diverse national and international markets, and a diversifying workforce. Are our water education programs sufficiently preparing the current and future workforce to meet these challenges? This session will highlight challenges and successes in workforce development related to careers in agriculture water management addressing both professional development and capacity building in scaffolded education. Talks will span the spectrum of K-Gray addressing STEM education and recruitment, curricular development, credit and non-credit professional development, and continued workforce training leading to in-demand, skilled, collaborative, and diverse water managers that sustain agriculture in the current and future environment.

Building and Researching Stakeholder Engagement for Water Quality and Quantity Management: The Water for Ag Project

Kathryn Brasier, Penn State University (M. Burbach, W. Eaton, L. Fowler, W. Whitmer, C. Williams)

Community-led processes that include stakeholders are increasingly advocated and adopted by scholars/scientists, practitioners, and policymakers alike. However, the processes and outcomes of these stakeholder engagement approaches are not fully understood or identified. From 2017 through 2022, the USDA-NIFA funded Water for Agriculture project has worked in five locations in Pennsylvania, Nebraska and Arizona to implement and study such community-led engagement efforts to address water quality and quantity challenges. We convened broadly representative groups of diverse stakeholders with whom we facilitated in-depth community engagement processes. Within each "local leadership team," we sought to foster local capacity-building, trust and relationship building, and knowledge co-production to address the issues most important to them. We employed a robust social and biophysical data collection process to identify outcomes and evaluate the effectiveness of the community engagement strategies employed across these differing contexts. In total, we have conducted in-depth interviews with more than 160 key stakeholders, conducted pre and post community and producer surveys in each site, held 77 local leadership meetings and numerous other community-based events and workshops, initiated 3 biophysical research projects, acquired additional funding to support locally-driven activities and workshops, held a wide range of meetings with key state and regional policy-makers, published, developed or have under review 24 peer-reviewed journal articles, conducted more than two dozen presentations, workshops and seminars, and developed an online guidebook for practitioners. This presentation highlights the results of this project and discusses potential implications for similar efforts to engage stakeholders in managing natural resources.

Transforming Drainage: Storing Water in the Landscape to Increase Resiliency and Reduce Nutrient Losses

Jane Frankenberger, Purdue University

Drained lands, which comprise about 25% of US cropland, can experience both water excess and water deficit and provide pathways for excess nutrient losses The USDA NIFA-funded Transforming Drainage (https://transformingdrainage.org/) project team worked to increase water storage in agricultural drainage systems through research, tool development, engagement with implementation agencies, outreach, and education. The project team published 40 peer-reviewed papers including synthesis papers across sites showing that drainage water storage practices (controlled drainage, saturated buffers, and drainage water recycling) can significantly reduce nutrient losses from drained land while maintaining or increasing yield across the Midwest region. The database from the 39 subsurface drainage research sites where drainage storage practices were evaluated has been uploaded to the National Ag Library Ag Data Commons, representing a major advance in making data publicly available for future research. The team developed eight free online tools that allow stakeholders to make better decisions about drainage design to protect water quality and improve resilience. To further support implementation of practices advanced in this project, the team worked extensively with federal and state agency staff and contributed research findings to support two USDA NRCS Conservation Practice Standards. In order to continue the work of the project into the future, team members organized and led the development of the Conservation Drainage Network to strengthen the network of the drainage industry, conservation agencies and non-governmental organizations, and researchers to continue to advance agricultural drainage and water quality.

Stakeholder-Driven Modeling in Support of Groundwater Sustainability: the Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) Project

Wendy Graham, University of Florida (D. Adams, K. Athearn, W.L. Bartels, P. Carton de Grammont, C. Court, M. Dukes, J. Ferreira, R. Hochmuth, D. Kaplan, J. Lai, J. Love, M. Monroe, K. Schlatter (University of Florida); G. Cowie, M. Masters, K. Rowles, (Albany State University); P. Dwivedi, C. Furman, W. Porter, A. Smith, G. Vellidis, (University of Georgia); L. Kalin, R. Karki (Auburn University))

The Upper Floridan Aquifer (UFA) is among the largest, most productive aquifers in the world and is a vital regional resource shared between Florida, Georgia, and Alabama. The UFA supports agricultural activities worth >$7.5 billion and supplies drinking water to more than 10 million people but faces significant threats to water quality and quantity which could potentially harm food security, fiber production, and vital ecosystem services. The USDA-NIFA funded Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) project brought scientists and stakeholders together in a Participatory Modeling Process to understand the economic-environmental tradeoffs associated with alternative climate, land use, and Best Management Practice (BMP) adoption scenarios, with the goal of understanding changes needed to achieve agricultural water security and environmental protection. This presentation will highlight successes, challenges and outcomes of this five-year project including field experiments that measured yields and water and nutrient balances of alternative cropping systems and BMPS; co-developed biophysical and economic models that simulated farm/forest-scale and regional scale economic-environmental tradeoffs for current conditions and alternative future scenarios; stakeholder preference research that evaluated producer willingness-to-accept and public willingness-to-pay for incentives to achieve promising land use and/or management changes; social learning research that shaped the design and evaluated the success of the Participatory Modeling Process; and science communication research that evaluated alternative methods to frame and communicate key project messages beyond the project participants.

The Future of Water in a Desert River Basin Facing Climate Change and Competing Demands: A Holistic Approach to Water Sustainability in Arid and Semi-Arid Regions

Alex Mayer, University of Texas at El Paso; Alfredo Granados-Olivas, Universidad Autónoma de Ciudad Juarez (W. Hargrove, H. Josiah, A. Mirchi, A. Granados Olivas, G. Ganjegunte, D. Gutzler, D. Pennington, F. Ward, L. Garnica Chavira, Z. Sheng, S. Kumar, N. Villanueva Rosales, W.S. Walker)

The focus of this interdisciplinary, international project was the Middle Rio Grande (MRG) basin, including parts of southern New Mexico, Far West Texas, and Northern Chihuahua. The MRG is challenged by changing climate, agricultural intensification, growing urban populations, and a segmented governance system in a transboundary setting. The core question we addressed is: how can water be managed so that competing agricultural, urban, and environmental sectors can realize a sustainable future? We developed and synthesized results for "water futures", considering possible, probable, and preferable outcomes from the known drivers of change in the MRG in a stakeholder participatory mode. We accomplished this by developing and evaluating scenarios using a suite of scientifically rigorous computer models, melded with the input from diverse stakeholders. Under likely future scenarios without significant interventions, relatively cheap and easy to access water will be depleted in about 40 years. We evaluated technologically possible interventions, all of which will result in more costly water. For agriculture, these included: 1) alternative sources of water, especially desalination of brackish water; 2) alternative methods of irrigation, especially drip irrigation; 3) improved water management, especially ET-based irrigation management; 4) improved salinity management; and 5) alternative crops, none of which are economically viable. Similarly, possible but more expensive interventions for urban centers included: 1) more desalination, 2) direct potable re-use, and 3) imported water. Urban conservation related to outdoor water use also could be efficacious to a degree. However, water management across all sectors and jurisdictions, including binational cooperation, must be improved to realize a more sustainable future. A new approach is called for based on "adaptive cooperation" among sectors and across jurisdictions along four important themes: information sharing, water conservation, greater development and use of alternative water sources, and new limits to water allocation/withdrawals coupled with more flexibility in uses.

Engaged Research to Inform Management and Governance of the Ogallala Aquifer

Meagan Schipanski, Colorado State University (A. Kremen)

The Ogallala aquifer, the largest unit of the hydrologically connected High Plains aquifer system, is one of the world's largest fresh groundwater resources. Decades of pumping at rates greater than natural recharge from precipitation has led to significant water level declines across many parts of the aquifer, impacting agriculture and rural communities across the region. The Ogallala Water Coordinated Agricultural Project (2016-2021) aimed to support the optimization of groundwater use and precipitation in the Ogallala Aquifer region to sustain food production systems, rural communities and ecosystem services. Stakeholder concerns regarding groundwater use provided a natural opportunity to convene diverse perspectives, interdisciplinary research, and build multi- state partnerships and approaches. Our 70-member team from 10 institutions worked across multiple scales, including at the scales of: 1) individual producers, 2) local and regional areas, such as groundwater management districts, 3) the broader multi-state aquifer region, and 4) cross-scale programs. Through this integration, the team developed new tools, approaches, and partnerships to inform future water management research and outreach. The team's research resulted in new integrated models for communities to evaluate economic and agronomic impacts of different policy and management scenarios. The team's outreach resulted in the development of multi-state training and extension programs, adoption of irrigation technologies across thousands of acres, and new state-level policies and policy proposals to facilitate groundwater conservation. We identified how water managers in this unique semi-arid production area can benefit from more flexible policies, including voluntary collective commitments to limit pumping, new limited irrigation crop insurance options and programs that help producers maximize profit rather than focusing on maximizing yield. While there is no "no one-size-fits all" solution for the water challenges of the region, many sound strategies, tools and widespread social will exist to support more profitable and climate-resilient production systems.

Developing and Promoting Water-, Nutrient-, and Climate-smart Technologies to Help Agricultural Systems Adapt to Climate and Societal Change

Ames Fowler, Michigan State University (B. Basso, 1st author)

The balance between producing more nutritious food for a growing population, protecting the environment on which lives and livelihoods depend, and providing economic opportunities in rural communities is becoming increasingly precarious. A new array of challenges faces agriculture in the coming decades related to complex tradeoffs among food production, energy generation, and resource use against a background of more variable weather and changing global markets. Digital agriculture has the potential to revolutionize farming by fundamentally changing how individual producers make choices and collectively act to manage environmental impacts. The talk will discuss how environmental and economic performance of US row-crops can be substantially improved by using digital agriculture to identify consistently unprofitable subfield areas – that can then be managed differently to provide economic and environmental benefits. Ultimately, a geospatial systems approach can provide greater farm profitability, climate mitigation, and biodiversity conservation.

Expanding Capacity and Potential: Mini-grant Programs to Jumpstart Local Efforts

Lexi Firth, Mississippi State University (B. Baker)

Developing effective peer-learning and on-farm conservation demonstration programs requires interdisciplinary approaches with strategies that both meet funder goals and producers where they are, on diverse operations, with significant environmental, economic, and social challenges in local communities. Farmer-led conservation efforts engage local communities on a personal level, often reaching peers that are less receptive to conservation education when administered by an official organization. Mini-grants provide resources to implement local farmer-led efforts, building the capacity of farmers to support and lead water quality and land stewardship. Insights from mini-grant projects offer opportunities to learn from successful programs and adapt to other regions. Through the EPA Farmer-to-Farmer initiative, the project team developed and delivered a competitive mini-grant program to award four grants in the amount of $4000 annually for three years to support farmer-led conservation education and outreach across the basin. A total of 48 applications were received across the states of WI, MN, KY, IN, IL, AR, and MS, of which 12 were funded. Most applicants were from upper river basin, where existing state-level funding to support local farmer-led groups often already existed. In addition, common methods for conservation demonstration were field days and management trials, with most efforts concentrated on cover crops and nutrient management. The strong focus on these management practices suggests information and expertise on other types of conservation management strategies is limited. Mini-grant applicant characteristics highlight important potential target areas for future conservation effort and support.

Farmer-Led Watershed Groups: Key Resources and Partnerships for Success

Mike Daniels, University of Arkansas Coop. Ext. (B. Baker, L. Firth, A. Gumbert, J. Seifert)

Nonpoint source pollution from agriculture is difficult to address and resolve given the diffuse nature of the source and complex arrangement of private farms and the vast array of different land use and management practices among farms and among fields within a farm. Adding to the complexity is the fact that local water issues are best resolved at the watershed scale while agricultural producers manage at the field and farm scale. Due to the lack of definition and quantification of scientific relationships that govern nonpoint source pollution from the edge of a management unit such as an agricultural field and the receiving water body that integrates all land use activities, farmers are often isolated from watershed solutions as it is difficult to quantify both in terms of profitability and water quality enhancement results if a producer makes a change in management. The watershed approach embraced by EPA has prompted the formation of many watershed-based organizations to voluntarily address local water issues, however many of these organizations lack participation from the agricultural community which can limit communication among agriculture and other sectors of society, thus limiting the effect of watershed efforts. Involving farmers in watershed leadership is imperative to overcoming these obstacles. Involving agricultural producers in the "solution" process will promote more effective efforts to nonpoint source pollution from agriculture. Different means of developing farmer-led watershed efforts will be reviewed and discussed.

Farmer Engagement through Action

Rachel Curry, University of Illinois Extension (L. Christianson, R. Christianson)

Water quality-related conservation adoption by farmers is low, with cover crop adoption in Illinois less than 10% and adoption of edge-of-field practices like denitrifying bioreactors even lower. Barriers associated with conservation adoption are many, though direct cost and return are key elements in the decision-making process. For this work, a cover crop program was established over a three-year period by working with a Soil and Water Conservation District (SWCD) in the Lower Rock Creek watershed in Illinois. Working with that same partner, a field day was held during the installation of an innovative denitrifying bioreactor design. The cover crop program resulted in 270, 570, and 1044 acres of cover crops, providing an estimated 1,385, 2,924, and 5,356 pounds of nitrogen reduction (76, 161, and 294 pounds of phosphorus reduction) in 2020, 2021, and 2022, respectively. The bioreactor, built in the fall of 2021 is estimated to provide 240 pounds of nitrogen reduction every year over the next 10 years. Working with the local SWCD, trusted in the community, was an integral part of making both of these programs successful.

Effectiveness of Farmer Outreach and Engagement Methods to Encourage Cross-basin Idea Pollination
Amanda Gumbert, University of Kentucky (A. Mase, B. Isidore)

Peer-to-peer learning is an effective and preferred way for farmers to learn new practices. Land-grant university partners collaborated on three peer learning approaches to engage farmers in conservation practices and land stewardship. An in-person farmer exchange in February 2020 brought farmers and farm advisors to Mississippi Delta-area farms to discuss successes and challenges with conservation practice implementation. Post-event evaluations showed 67% of participants planned to adopt a conservation practice they learned about; 100% of respondents learned practices to save money on farms they manage or advise; and 100% gained confidence to implement a conservation practice. A virtual farmer shop talk series in winter 2021 attracted 200+ participants from 18 states. Each unique session of the four-part series featured a farmer and farm advisor presentation followed by facilitated small group discussion. Post-event evaluations indicated 89% of respondents learned about practices that would save money on their farms; 78% learned about a resource to help them implement conservation practices; and 89% gained confidence in their ability to implement conservation practices. An in-person land stewardship summit held in June 2022 brought together 50 farmers, farm advisors, agency representatives, NGOs, and academics. Participants visited two Wisconsin farms to learn directly from farmers sharing their experiences with conservation and farmer-led watershed leadership. Post-event evaluations indicated 95% of respondents feel more connected to a community of conservation-minded farmers and professionals; 95% indicated it was important to hear directly from farmers about conservation practice implementation; and 74% identified a new conservation opportunity as a result of the summit. Farmers from across the Mississippi-Atchafalaya River basin interacted with farmers managing land in a variety of climatic and soil conditions. Participants were able to hear straight talk from their peers on cover crops, no-till, and nutrient management while learning exploring ways farmers can be effective watershed leaders.

Evaluative Thinking: A 'Best Management Practice' for Effective Programs

Brittany Isidore, University of Wisconsin-Madison (A. Mase)

Evaluators across the globe are engaging in transdisciplinary, collaborative applied research projects addressing complex water resource challenges. Evaluation is sometimes seen as a project add-on or a costly reporting requirement. Evaluators are shifting the narrative of how evaluation is being used in agriculture and natural resources research and extension programming. Moving away from evaluations that simply measure the results of an intervention against the stated goals and outcomes, many evaluators are now working with teams throughout the entirety of projects to maximize their success by using and teaching the skill of evaluative thinking. This skill serves as a pathway for teams to engage in critical thinking that helps them identify assumptions, pose thoughtful questions, pursue deeper understanding through reflection and perspective taking, navigate biases, and develop solutions that are informed by strong evidence, responsive to the context and priorities, and that maximizes the value of existing data resources. Journey with us as we share with you the tools we used to guide the goals, approach, activities and evaluation tools of a transdisciplinary multi-state research and extension project engaging farmers in leading conservation practices and land stewardship across the Mississippi-Atchafalaya River basin. We will also discuss the impact that using evaluative thinking had on the course of the project and understanding how the team adapted and thrived in spite of changes due to the covid-19 pandemic.

One Good Idea, the Not-Quite-YouTube for Conservation Farming Practices

Jenny Seifert, University of Wisconsin

Making changes to a farming operation often involves a level of risk that can make many farmers uneasy, even if it would mean long-term gains for their soil, land, and bottom line. This is one of several reasons why conservation farming practices, which often have co-benefits for water, have yet to become widely adopted by farmers. Yet, there is a promising leverage point that a new online platform for farmers is, well, leveraging: farmer-to-farmer learning. One Good Idea (goodideafarm.org) is a multi-media clearinghouse for farmer-to-farmer learning about soil and water conservation practices that aims to help farmers learn from each other about how they can adapt their operations to be more profitable and more restorative for soil and water resources. Through crowdsourced videos and podcasts, farmers can learn practical ideas from other farmers who are doing these practices already. It is based on mounds of research showing that farmers often to look other farmers for information that can help their operations, especially when they want to try something new – they want to learn from someone like them who has been there and done that. One Good Idea is a collaborative effort of land grant university Extension and farmers, and there are several ways water professionals can plug in. This presentation will be an overview of One Good Idea, the science behind it, and how it could support the goals and programming of water professionals who engage with farmers about conservation practices.

Edge of Field Runoff Analysis following Grazing and Silvicultural Best Management Practices in Northeast Texas

Lucas Gregory, Texas A & M University (K. Wagner, E. Rhodes, J. Gerlich, H. Starns)

Landowners and natural resource agencies are seeking to better understand the benefits of best management practices (BMPs) for addressing water quality issues. Using edge of field and edge of farm runoff analysis, we compared runoff volumes and water quality between small watersheds where BMPs (e.g., prescribed grazing, silvicultural practices) were implemented and control watersheds managed using conventional practices (i.e., continuous grazing, natural forest revegetation). Flow-weighted samples, collected over a 2 year-period using automated samplers, were analyzed for nitrate-nitrite-nitrogen (NNN), total Kjeldahl-nitrogen (TKN), total phosphorus (P), ortho-phosphate phosphorous (OP), total suspended solids (TSS) and *Escherichia coli (E. coli)*. Comparison of silvicultural planting to conventional reforestation practices showed a significant decrease in NNN loads ($p>0.05$) but no significant differences in TKN, P, OP, TSS or *E. coli.* Continuously grazed sites yielded ≥ 24 % more runoff than sites that were under prescribed grazing regimes, despite receiving less total rainfall. Likewise, NNN, TSS, and TKN loadings were significantly less under prescribed grazing management than on conventionally grazed sites ($p < 0.05$). Data suggest that grazing BMPs can be an effective tool for rapidly improving water quality. However, silvicultural BMPs require more time (i.e., >2 years) to establish and achieve detectable improvements.

New Practices for Water Quality Enhancement in Missouri

Gurbir Singh, Assistant Professor (K. Nelson, G. Kaur)

Nutrient export from drained agricultural fields is the major cause of impairment of surface water quality. The edge of field practices that have been developed to reduce nutrient loading from artificially drained agricultural fields include bioreactors and saturated buffers. A bioreactor uses a carbon source (such as wood chips) to reduce the concentration of nitrate nitrogen in subsurface agricultural drainage flow through enhanced denitrification. Previous studies have shown that bioreactors can remove 12-98% of the annual nitrate loads, need little to no maintenance, have good retention time, and can last up to 20 years. In saturated buffers, the drainage water flows as shallow ground water through the riparian vegetation which can take up >40% of the nitrate-N. A study conducted in Northern Missouri from 2018 to 2022 showed that controlled drainage increased corn and soybean yields by 19-33 and 4-7 bu ac^{-1} compared to the non-drained treatments. Bioreactor and saturated buffers showed reduction in average annual discharge, annual nitrate and total-P loads. Bioreactor and saturated buffer reduced average annual nitrate-N by 66% and average annual total-P loss by 36%, with 1.12% reduction in annual discharge.

Monitoring Algae Blooms in Small Lakes Using Drones: A Case Study in Southern Illinois

Ruopu Li, Southern Illinois University-Carbondale (D. Wu, J. Liu, N. Khan)

Harmful Algae Blooms (HABs) persist in many water bodies around the world and pose adverse health and economic impacts to the affected communities. Small Unmanned Aerial Vehicles (UAVs) have recently been applied as a cost-effective tool for HABs monitoring. In this study, HABs in two small lakes in Southern Illinois (Carbondale Reservoir and the Campus Lake of Southern Illinois University) were monitored using UAVs and biomass concentrations in lake waters. By analyzing vegetation indices derived from multispectral UAV images and chlorophyll-a concentrations in the two lakes, statistical regression models were established for each waterbody. The model relates spectral characteristics of the lake water to its algae biomass. It was found that normalized difference vegetation index (NDVI) and blue-to-green band ratio are the best-fit indices to the variation in chlorophyll-a in Carbondale Reservoir and the Campus Lake, respectively. The findings in this study can be used for monitoring HABs using UAVs in these lakes in the future.

A Recurrent Neural Network Approach to Predict Harmful Algal Bloom in a Lake Using Continuous High Frequency Data

Ibrahim Busari, Clemson University (D. Sahoo, R. Jana)

Decision support tools like data-driven models are becoming crucial for HABs detection due to improvements in sensing technologies, communication tools, and advancements in computing prowess. However, prediction of HABs before occurrence often comes with some uncertainties, which are linked to the frequency of observed data. This current study was focused on the effect of water quality data frequency on chlorophyll-a predictions in Boyd Millpond, located in South Carolina. A Bayesian linear regression model was fitted on chlorophyll-a concentrations obtained from laboratory processing of periodic samples and corresponding chlorophyll-a concentrations from sensors to obtain continuous laboratory-quality chlorophyll-a concentration, used as an index of HABs. Water quality datasets were resampled into hourly, six-hours, twelve-hours, and daily timesteps and fed into an Long Short-Term Memory (LSTM) model to predict HABs and prediction accuracy compared using Root Mean Square Error (RMSE). Prediction uncertainty was quantified using the Monte Carlo Dropout technique. Using the mean chlorophyll-a concentration derived using the Bayesian regression as the index of HABs, the study showed that using 3-days prediction horizon, *daily datasets* corresponding to a lookback of 3-days have the lowest RMSE value of 2.69 µg/l. In contrast, for a 7-days prediction horizon, the *hourly dataset* with a lookback of 168 hours (7-days) has the lowest RMSE value of 2.52 µg/l. This same pattern was observed when the upper bound of chlorophyll-a concentrations was used as a target with an RMSE value of 2.54 µg/l for the daily dataset and 2.66 µg/l for hourly observations, respectively. The broader outcome of this research will enable the timely detection of HABs and will aid in understanding the data sampling, data transmisson and data storage needs, which are often the critical elements for data-driven modeling.

Thresholds and Hierarchical Structure in Cyanobacterial Harmful Blooms, Lake Fayetteville, Four Years of Data

Brian Haggard, Arkansas Water Resources Center - University of Arkansas Division of Agriculture

Cyanobacterial harmful algal blooms (cyanoHABs) are more frequently observed, or maybe they were always there and we are just now looking for them in smaller run of the river impoundments. We have been monitoring lake Fayetteville on a near weekly basis, since 2019. Water samples have been collected at multiple sites, and basic physiochemical properties recorded (temperature, conductivity, dissolved oxygen, and pH). samples are analyzed for dissolved and total nutrients, dissolved trace elements, algal pigments and raw fluorescence, and total and free microcystin concentrations. In 2020, we started collecting surface scum samples when observed, and then in 2021 we regularly collected surface scum whether cyanobacterial scum was observed or not. These data will be explored using nonparametric change point analysis (nCPA), classification and regression tree analysis (CART), and random forest models to understand the annual and interannual drivers of cyanoHABs. Preliminary analysis suggests that top thresholds and hierarchical structure might vary annually, leading to challenges in understanding and management this freshwater issue.

Occurrence and Characteristics of Microplastics in Urban Rainwater Runoff and in Oysters from the Mississippi Gulf Coast

James Cizdziel, University of Mississippi (K. Wontor, M. Bee, B. Olubusoye)

Awareness of microplastics (MPs) as a global pollutant continues to grow among scientists, politicians, and the public. MPs are a diverse suite of contaminants that range in size from 1 µm to 5 mm and that occur in a variety of shapes. The Mississippi River acts as a conduit continually transporting plastic litter in runoff to the Gulf Coast where MPs accumulate and can affect susceptible organisms. Filter-feeding species, like oysters, are particularly vulnerable. The proportion of MPs in aquatic ecosystems stemming from urban runoff has grown with urbanization. Here we report our findings on MP pollution in runoff from parking lots and roads in Oxford, MS as well as in oysters (*Crassostrea virginica)* from the Mississippi Gulf Coast. We used a YSI ProSampler to collect rainwater runoff at locations in Oxford MS, conducted a density separation to isolate MPs, and used stereomicroscopy and FTIR micro-spectroscopy to characterize the particles. We observed >150 MPs/L at the start of the rain event, with concentrations declining with time. Most MPs were fragments (~80%), followed by fibers (~18), and most (~80%) were <200 µm in size. MPs were mainly composed of polyethylene, polyester, polypropylene, polyvinyl chloride, and polystyrene. For oysters, locations inside bays near population centers had higher average concentrations. Oysters seem to accumulate more MPs on their external tissues than in their digestive system. MP concentrations in oysters was not correlated with oyster condition index. Further characterizing the types of MPs present in oysters may provide insight into likely sources of contamination at different sites. Overall, this work provides much-needed empirical data on the abundances and sizes of MPs in both urban runoff and in oysters from the Mississippi Sound, and suggests that lawmakers need to consider federal legislation to address MP pollution in river systems at a national level.

Cornerstone at the Confluence: Navigating the Colorado River Compact's Next Century
Jason Robison, University of Wyoming

Described as the most institutionalized river system in North America, the Colorado River system is managed in accordance with a labyrinthine body of laws and policies colloquially called the "Law of the River." The Law of the River's proverbial cornerstone, the Colorado River Compact, turned 100 years old last year, amidst a confluence of unrelenting water management challenges. Hailing from a host of fields across the social and physical sciences—and with some humanities and fine arts coverage as well—a group of 21 collaborators commemorated this anniversary by preparing a centennial volume, *Cornerstone at the Confluence: Navigating the Colorado River Compact's Next Century*, published in November 2022 by University of Arizona Press (link). *Cornerstone* looks backward and forward in time. It reflects on the conjoined history of the Colorado River system and the Law of the River since 1922, as well as offers diverse visions of how the Law of the River might evolve, and what the Colorado River Basin might become as a place, moving forward from 2022. A variety of salient subjects are examined from this intertwined retrospective and prospective angle: environmental protection (*e.g.*, Colorado River Delta restoration); transboundary apportionment (*e.g.*, climate change's impacts on the river system's hydrology); Indigenous Peoples (*e.g.*, inclusion of tribal sovereigns and respect for their water rights); and, perhaps most critically, governance (*e.g.*, evolution of decision-making bodies and processes surrounding the river system). Each of these subjects (and others) implicates a fundamental tenet of transboundary water law and policy: "equity." *Cornerstone* considers our collective commitment to equity at a time when, in palpable, mind-bending terms, the confluence of contemporary circumstances facing the river system and the Law of the River are as historic as the cornerstone's anniversary.

Arizona Colorado River Visualization Enterprise

Kathryn Sorensen, Arizona State University

The Kyl Center for Water Policy, working in partnership with the Arizona State University Decision Theatre, is developing more robust, transparent, and accessible decision support for the benefit of Arizona's Colorado River users and stakeholders.

Working with industry experts, we are developing a large array of Colorado River hydrologic scenarios—utilizing a Colorado River Simulation System platform—to more fully define the decision space for Arizona stakeholders across scenarios involving different hydrology, water demands, management rules, and climate-change impacts. We also integrate the capabilities of localized models to translate these scenarios into local impacts in terms of water availability on individual community water systems, agricultural districts, Indian Communities, and industries across multiple years. These models factor in the availability of other water supplies such as the Gila, Salt, and Verde Rivers, reclaimed water, and groundwater. Working from that platform, we engage the advanced visualization capabilities of the Decision Theater to develop new ways of analyzing, seeing, and communicating climate-change risks, demand-management implications, potential solutions, and other key information to stakeholders. We refer to this effort as the Arizona Colorado River Visualization Enterprise—the CuRVE.

Rethinking Our Relationship with Nature: The Binational Restoration Process for the Colorado River Delta

Osvel Hinojosa-Huerta, Cornell University

The Colorado River today rarely flows to the sea. After a century of desiccation and water development under a legal framework that did not recognize the environment as a legitimate water user, the 600,000-ha delta ecosystem has been reduced to a mere 10% of its original size. However, during the last 25 years, the Colorado River delta in Mexico has been under a binational recovery process, shifting the relationships between water users and nature. Environmental NGOs, academic institutions, agencies and stakeholders from the United States and Mexico have worked together to restore riparian and wetland habitats and re-establish a modest connection between the flowing Colorado River and the Upper Gulf of California. In the context of a broad dialog to improve Colorado River management at the border and advance sustainability goals in the basin, the two countries have adopted a series of formal, diplomatic agreements that address a suite of mutually beneficial activities that includes environmental restoration. The agreements include commitments of resources (funds and water) towards a collaborative effort between federal, state, and local governments, NGOs, universities, and stakeholders to initiate environmental restoration activities, while a binational science team informs policy formation and evaluates program implementation. As a result of these binational agreements, 34,000 hectares of priority wetlands have been restored and protected. These restoration outcomes are based on continuous work on governance, science-based planning, public policy, mechanisms to secure land and water for nature, community engagement, and the implementation of a monitoring program to evaluate the ecosystem responses.

Improving CRB Resilience through Incentives for Reduced Use

Hannah Hansen, Salt River Project; Bonnie Colby, University of Arizona

Major cities located in the Colorado River Basin (CRB) rely on various types of economic incentives to reduce water use and improve supply reliability, through programs provided by cities themselves and by state and federal agencies. Urban water use trends across CRB generally exhibit declining per capita use and most large cities have adopted municipal rate structures designed to incentivize lower use. Incentive-based programs to protect watershed health and water supply also are being implemented through programs and partnerships across the CRB. Agricultural irrigation consumes a large portion of water resources in the CRB and worldwide. New statistical models of central Arizona cropping patterns, agricultural water use and irrigation intensity examine how these farm choices are affected by federal agricultural support programs, crop prices and weather. This provides insights for addressing agricultural components of our current water challenges in the CRB.

The Irrigation Innovation Consortium: A Five-Year Retrospective

Amy Kremen, Colorado State University (T. Martin)

Since launching in 2018, the Irrigation Innovation Consortium (IIC) has supported more than forty public-private research collaborations. Each of these projects has focused on advancing knowledge, tools, and/or strategies related to effective, efficient irrigation management tools and strategies. IIC project funding and other support has been provided by industry and academic partners, matched with additional funds from the Foundation for Food and Agricultural Research (FFAR) for an investment totaling more than $10 million over five years. IIC's body of work covers both irrigated landscapes and irrigated agriculture. Most of IIC's projects have been located in the western half of the U.S., and as such, have focused on addressing critical questions pertinent to water managers and others who are navigating water resource quantity and/or quality declines or related constraints. This presentation will provide a retrospective review of key results and insights from IIC-supported work to develop and test irrigation hardware and software, decision support tools and system integrations. In addition, lessons learned related to engaging academics and industry on pre-competitive research and perspective on science translation and outreach to address producers' lag in adoption of advanced irrigation management tools and strategies will be shared.

Sustainability of Irrigated Agriculture Under Changing Climatic Conditions

Scott Bradford, USDA ARS

Climate models for California are predicting warmer conditions, reductions in the mountain snowpack, and more extreme heat waves, droughts, and precipitation events. These climate changes are expected to adversely impact the sustainability of agriculture because irrigation is more dependent on diminishing groundwater supplies. The USDA, ARS, SAWS unit in Davis, CA has recently been established to increase the efficiency and sustainability of irrigated agriculture in the Central Valley, CA. This presentation highlights ongoing and planned research activities within the SAWS unit. On-farm strategies to capture episodic flood water for managed aquifer recharge (MAR) is one focus area. Field studies and geophysical measurements are being conducted to characterize subsurface heterogeneity and to assess and optimize the performance and location of various MAR approaches. This information is being used in conjunction with mathematical models to better quantify infiltration, recharge, contamination fluxes, groundwater-surface water interactions, and vadose zone processes at the field and watershed scales. Treatments and MAR designs are being developed to minimize potential adverse impacts on crop production, groundwater quality, and clogging. For example, model results show that the use of a 1 m diameter by 30 m deep drywell can infiltrate as much water as a 70 m diameter infiltration basin, but the recharge occurs much more rapidly and bypasses low permeability layers. Improving irrigation efficiency is a second focus area of the unit. A combination of remote sensing, field micrometeorological and biophysical measurements, and mathematical modeling are being used to improve estimates of crop evapotranspiration (ET) for this purpose. Results show that improved irrigation efficiency can be achieved by accounting for observed spatial and temporal variability in crop ET. Economic analyses of long-term observations of MAR and irrigation efficiency are being employed to assess impacts on the food-energy-water nexus and sustainability under changing climatic conditions, water resource demands, and water allocations for irrigation.

Panel Discussion: Addressing Groundwater Depletion across Regions and Aquifers

Organizer: Drew Gholson, Mississippi State University

Panelists:

Drew Gholson, Mississippi State University
Kevin Wagner, Oklahoma State University
Lucia Levers, USDA ARS, Sustainable Agricultural Water Systems (SAWS) Unit
Nicolas Quintana, Mississippi State University
Amy Kremen, Colorado State University
Scott Bradford, USDA ARS

Interstate Collaboration and Barriers to Transboundary Water Management

Organizers: Beth Callaway, Interstate Council on Water Policy; Steven Buck, University of Kentucky/Western Water Network

Panelists:

Beth Callaway, Interstate Council on Water Policy
Steven Buck, University of Kentucky/Western Water Network
Stephanie Nummer-Fantozz, Interstate Commission on the Potomac River Basin
Rachelle Eby, SRBC
Jeff Cowley, Wyoming State Engineer's Office

This session focuses on interstate collaboration for water management. The session is led by members of the Interstate Council on Water Policy, which is a national nonprofit organization representing state, interstate and regional water managers from across the US. In the last 20 years, natural disasters (extreme heat, wildfires, record droughts and floods) have caused more than $1.5 trillion in damage and economic losses across the United States. Increasing disaster costs and impacts pose a growing threat to livelihoods, infrastructure, supply chains, and national security. We will consider recent efforts to bring together federal, state, and local government, business, and NGO leaders to devise policy solutions that improve community resiliency around water resources. Speakers will cover **water planning** at the interstate level in the context of climate change and extreme weather events and **interstate collaboration on managing water data** across state lines. Water use measurements, estimates and reporting are important to both water supply planning, drought response planning and mitigation, water project construction and operations, water policy and water rights administration. Yet, state and federal agencies face challenges in estimating and reporting water use to make informed decisions. We consider how states (including IT and water resources managers) are working together to share developments on water use data sharing methods. We discuss recent efforts on data sharing, offering lessons learned and recommendations for stronger interstate data sharing partnerships.

Science Communication Workshop
Facilitators: Amy Kremen and Ashley Patterson, Colorado State University

Getting clear on why you're sharing science: Bring a key theme, idea, or message you want to develop during this 90-minute session, along with your science communication frustrations, goals, or just an open mind!

This interactive workshop will guide you to:

- Clearly articulate why you are sharing your science idea(s), and with whom
- Develop compelling and actionable messaging for your particular audience(s)
- Set goals for integrating scicomm intentions and practice in your professional activities

An Agent-Based Model of Agricultural Water Markets under Appropriative Rights and Droughts
Reetwika Basu, Washington State University

The efficient allocation of water is a prime concern in many countries worldwide. Most western states in the U.S. use some version of a prior appropriation system for groundwater and surface water use. During a drought in which junior rights are curtailed, the transfer of senior appropriative water rights may increase the productive value of water by allowing it to be transferred to higher-valued uses. Transferring an appropriation right is not a simple transaction between two parties. An agent-based model (ABM) of agricultural water markets is developed to simulate trading (transfer of appropriation rights) at the watershed scale in response to drought. The model allows for variation in farm characteristics, water rights seniority, diversion location in the watershed, differences in agent preferences and information, and alternative market frameworks. We use the model to examine the effect of drought on trading activity and gains from trade under two different trading scenarios: Bilateral trading with random matching and a "Smart Market" that actively matches bidders to maximize gains from trade and the value of water. We also simulate the effect of non-pecuniary factors, such as preferences for active farming versus leasing and fallowing. Our results suggest several patterns. Gains from trade and market participation are more significant with moderate drought severity than with extreme drought or weak drought. Gains from trade and trading activity are also highest when a smart market matches bids and offers and when senior water rights holders prefer active farming to lease and fallow. The applications presented in this paper illustrate the broad applicability of the ABM framework to water resource problems under the appropriative water rights systems of the Western United States.

Anticipatory Effects of Regulation: The Case of California's Groundwater
Ellen Bruno, UC Berkeley (N. Hagerty)

Natural resource management policies often face a long implementation horizon. This can allow for a smooth transition, or alternatively introduce perverse incentives as producers race to extract the resource or establish claims to future allocations. We study how producers respond to California's Sustainable Groundwater Management Act (SGMA), a major shift in groundwater regulation that does not bind until 2040. We document that investments in perennial crops have increased by nearly 50 percent since SGMA passed in 2014, likely “locking in” water demand and raising future costs of compliance. However, we find that this pattern has occurred despite the policy, not because of it. Field-level comparisons across hundreds of agency borders reveal a precisely estimated zero effect of future pumping restrictions on the rate of perennial investment. This suggests the rational-expectations and rent-seeking effects of SGMA may balance out, leaving investment incentives unchanged on net.

Electricity Demand by the Irrigated Sector in Response to Climatic Shocks

Aaron Hrozencik, Economic Research Service - U.S. Department of Agriculture (M. Rouhi Rad, D. Uz)

Climate change is already impacting global agricultural with crop losses due to extreme heat projected to rise substantially through the end of the century. A rich economics literature characterizes how climate change impacts agricultural profits, land values, and yields. In regions with access to water resources for irrigation the agricultural productivity losses associated with climate change are less severe as producers as can potentially adapt to reduced precipitation and higher temperatures by applying more water to their crops. This paper addresses this form of climate change adaptation by characterizing how the irrigated agricultural sector responds to extreme heat and drought. Specifically, we use unique utility level data on electricity distributed to irrigated agricultural producers to empirically model how the sector's energy demand responds to climatic shocks. Our results shed light on an important form of climate change adaptation for the agricultural sector while also informing projections of electricity demand by the irrigated sector under differing climate change scenarios.

Corn Production and Groundwater Scarcity in the US High Plains

Gabriela Perez-Quesada, University of Tennessee (N.P. Hendricks)

Corn production in the semi-arid High Plains of the US is dependent on groundwater irrigation. However, declining groundwater resources can make continued irrigation inviable affecting irrigated crop supply. The study of the potential impact of aquifer depletion on corn production has been limited to the use of model simulations. We estimate how observed differences in the stock of groundwater affect corn production. To account for the endogeneity of groundwater stock, we exploit variation in current saturated thickness due to variation in pre-development saturated thickness. Simulation results reveal that the annual production of corn would decrease by 48.1 million bushels in the north portion of the High Plains Aquifer due to a uniform 10 ft decrease in saturated thickness, whereas the annual production of corn would decrease by 15.7 million bushels in the south. Further, we find that when initial saturated thickness is less than 70 ft, most of the impact on corn production of a decrease in the stock of groundwater occurs through an adjustment in irrigated acres in both the north and the south. When saturated thickness is larger than 70 ft, then the adjustment is mostly through a change in cropping patterns on irrigated land in the south but still through irrigated acres in the north.

The Economic Implications of Declining Snowpack for Tribal and Irrigated Agriculture Water Supplies
Nicholas Potter, USDA Economic Research Service

In the western U.S. snowpack makes up a substantial portion of available water supplies. Warmer temperatures can reduce snowpack, resulting in earlier and reduced spring runoff. In some basins, snowpack is expected to decline by 30 percent or more. The resulting decrease in available surface water supply has significant economic implications for native tribes, irrigated agriculture, and other water users across the western U.S. Water in this region is largely allocated under the framework of prior appropriations, where water rights are typically specified for a fixed quantity of water and for a priority date based on when the right was established. In 1908, the Supreme Court issued the *Winters* ruling, which recognized that tribal reservations included sufficient water rights to fulfill the purpose of the reservation. These rights are typically not quantified but are senior to many of the water rights owned by irrigators and other water users. As warmer temperatures reduce snowpack and corresponding available water supplies, uncertainty about the availability of sufficient water supplies to meet tribal, private, and public water rights is increasing. We estimate the impact of projected future climate on available water supplies for federally recognized tribal areas and water users in the surrounding basins. To do this, we first model the historical relationship between snowpack and climate and then use climate projections to estimate future snowpack. We map federally recognized tribal areas to upstream snowpack, which allows us to estimate changes in water supply. We use data on water rights for each river system to estimate water supply uncertainty for tribal areas and irrigators. Finally, we use data on the value of irrigated agriculture to characterize possible economic effects.

Paper Water, Wet Water, and the Recognition of Indigenous Property Rights
Leslie Sanchez, Rocky Mountain Research Station (B. Leonard, E. Edwards)

Restoring natural resource access for Indigenous groups has become a recent policy focus. We combine satellite data and robust difference-in-difference methods to estimate the causal effect of Native American water right settlements on land and water use on reservations in the western United States between 1974 and 2012. We find that settlements increase cultivated agricultural land use (crops and hay/pasture) by 8.7%. Our estimates of tribal water use indicate that, even after accounting for water leased off reservation, many tribes are utilizing only a fraction of their entitlements, forgoing as much as $938M--$1.8B in revenue. We provide evidence suggesting that this gap is driven, in part, by land tenure constraints and a lack of irrigation infrastructure.

Modeling Uncertainty in the Effects of Climate Change on Agricultural Land and Water-use
Munib Inam, University of Kentucky (S. Buck)

In this presentation, we will discuss the following questions: (i) How can we account for uncertainty when considering the effect of climate change on agricultural land and water-use? (ii) How can we usefully present uncertainty in the downstream effects of extreme weather patterns on flooding, production and environmental risks? (iii) Which types of extreme weather patterns matter most in terms of frequency and magnitude of effects on land and water-use as well as their downstream effects? The discussion will draw upon data and case studies on agricultural land and water-use in California and the Western United States.

Exploring the Use of Decision Making under Deep Uncertainty for Long-Term Planning in the Colorado River Basin

Rebecca Smith, Bureau of Reclamation (J. Prairie, A. Butler, C. Jerla, J. Kasprzyk, E. Zagona)

Reclamation has been following and funding research into how climate change may impact the Colorado River Basin (CRB) for over 15 years. After multiple studies showed large ranges of potential hydrologic futures, and an unprecedented drought continued to deepen, the need to find an approach to planning that could handle a high degree of uncertainty became apparent. Decision Making under Deep Uncertainty (DMDU) is a field of decision science that has developed methods and tools to overcome deep uncertainty, which occurs when it is not possible to say with certainty what is most likely to happen or which planning assumptions are most appropriate. Over the course of multiple studies, Reclamation has explored applications of DMDU to long-term planning in the CRB. This presentation will motivate the use of DMDU, review Reclamation's DMDU studies, and describe the role of DMDU in the upcoming process to develop new operational guidelines for Lakes Powell and Mead.

Collaborative Modeling as a Mechanism for Addressing Water Uncertainty

Kristi Hansen, University of Wyoming (K. Cooper, E. Donaldson, M. Keller, K. Landreville, G. Paige, J. Shinker, A. Van Sandt)

Human systems have generally been built to withstand prevailing weather and climate patterns in a particular location. Changes in temperature and precipitation (averages and degree of variability) and increased intensity of extreme weather events can overwhelm existing communities and infrastructure and threaten loss of life. These changes can make conventional methods of modeling water supply risk less useful than they have been in the past, just when careful and deliberate planning to prepare for weather extremes is needed more than ever. Such conventional modeling methods have often been criticized anyway for not being sufficiently transparent and comprehensible to the stakeholders they seek to serve. We present a trans-disciplinary project with a goal to engage Wyoming community members and decision makers in ways that empower them to adapt and transform their communities in response to climate change impacts. This work is presented in the context of other, similar transdisciplinary projects that also seek to work directly with communities in defining and modeling water-related natural hazards and climate change impacts. Dealing with climate change impacts is increasingly challenging, both for the scientists who model them and the communities who experience them. It is also challenging for the extension/other engagement professionals and policymakers who seek to bridge the gap between the science and communities. The collaborative, stakeholder-focused approach presented here brings community members into the process of articulating the risks they face and incorporates their understanding of these uncertainties into water decision-making processes. This presentation provides examples of ways to prepare water users and communities for greater uncertainty and to assist them in making decisions that reduce the impacts of uncertainty. It should prompt audience discussion of ways to utilize university extension resources, which are often embedded in local communities, in helping communities with preparedness for extreme weather events and flooding.

From High in the Sky to Deep Underground: Using Remote Sensing to Develop Estimates of Groundwater Pumping in the Upper Colorado River Basin

Nicholas Jadallah, Princeton University (R. Maxwell)

The Colorado River Compact–wrought with 100 years of controversy–is slated for renegotiation by 2026. With climate change forecast to further deplete river flows that have already fallen to precarious levels, better understanding the understudied interplay between groundwater pumping and water supply in the river's headwaters is critical for prudent water management. To study these processes in a worthwhile manner, a reliable groundwater pumping estimate in the upper basin (UCRB) is essential; however, groundwater pumping data are, at best, sparse.

Recently, workers have developed two novel ways to constrain groundwater depletion in the UCRB. One approach combines GRACE with other water storage datasets and uses a water budget technique to calculate aggregate groundwater depletion across the basin. However, previous applications of this method in the UCRB have resulted in vastly different conclusions. Another approach feeds various water management scenarios into an integrated hydrologic model (ParFlow-CLM) to see which scenarios cause the model's total water storage trend to most closely match that of GRACE.

This research advances both techniques. First, we examine the variability in the GRACE-water budget method and generate new water storage datasets to use in conjunction with GRACE. In particular, we quantify the variation across GLDAS/NLDAS soil moisture products, which explain much of the discrepancy in previous water budget results. Second, using water rights data and groundwater well location data, we will add a spatial dimension to the estimated groundwater pumping rates derived from the water budget approach. This will serve as a baseline for the suite of irrigation scenarios used in the ParFlow-CLM model simulations. Both strategies promise to further existing work and create an estimate of groundwater pumping that does not currently exist at the scale required to study the effects of groundwater extraction on water supply in the UCRB.

Riverine Fluxes of CO_2 and CH_4 of a Regulated River

Fernando Rojano, West Virginia State University (D. Huber, F. Guerrero, A. Hass)

Regulated rivers should keep water levels according to navigation, hydropower and recreation needs. In addition, these rivers must control water levels in urban areas to avoid flooding. These conditions favor an accumulation of allochthonous materials such as leaves, stems, organic matter, sediments and minerals in the shoreline. Since there are periodic inundations in the shoreline determined by the river stage, the allochthonous materials undergo physical, chemical and biological processes, turning into a hotspot of greenhouse gas emissions. Here we investigate the shoreline of a regulated river, the Kanawha River at the Central Appalachian Region, in order to know greenhouse gas emissions. The shoreline is defined by the river stage readings and identified by means of LIDAR maps. Along the shoreline we collected samples which were incubated in the laboratory. Then, measurements of diffusive CO_2 and CH_4 fluxes were conducted. It was found that after nine measurements of each sample we had emissions of (Mean±SE) 8729±879 and 340±76 µmol m^{-2} h^{-1} for CO_2 and CH_4 fluxes, respectively. Then, for a shoreline of 58 km river section, we have estimated fluxes of 61.02±6.51 and 0.91±0.21 kg/h for CO_2 and CH_4, respectively. Even though, this estimation may change due to sample composition, flooding periodicity and temperature along the shoreline; the laboratory conditions were seen as a way to overcome uncertainty from field conditions and also for adequately predict temperature-dependent fluxes along the year.

Inter-Professional Education for Drinking Water-Related Public Health Management

Matthew O. Gribble, University of Alabama at Birmingham

The Council on Education for Public Health (CEPH) is the primary accrediting body for public health programs in the United States. CEPH has a list of foundational competencies expected of Masters of Public Health (MPH) students, including interprofessional or intersectoral practice. MPH programs, to be accredited, are required to prepare their students to be able to "integrate perspectives from other sectors and/or professions to promote and advance population health." This creates a great opportunity for MPH degree programs to partner with educational institutions and professional organizations not traditionally part of the MPH training pipeline (e.g., hydrologists, engineers) on themes of shared concern, to help prepare students from multiple disciplines to better work at the interface of those disciplines in the professional lives following graduation. The relevance of safe and affordable drinking water for public health is widely appreciated, yet few training programs have integrated epidemiological, statistical, engineering, hydrogeological, policy, chemical and microbiological expertise. The Universities Council on Water Resources brings together experts from far-flung fields for transdisciplinary conversations about water resources. The purpose of this abstract is to highlight the ongoing need among CEPH-accreditation-seeking programs for interprofessional education (IPE) opportunities, and to encourage conversations about what those might look like and what partnerships could make sense in the context of training future practitioners in integrated water resources and public health management. The expectation of CEPH is that program graduates should be able to 1) cultivate and sustain mutual respect and shared values across professions, 2) appreciate the role of public health professionals vis-à-vis other professions, 3) communicate effectively in transdisciplinary conversations including the public and practitioners from fields other than public health, and 4) be able to apply these competencies in concert with others to address common goals (e.g., to foster programs and policies that are efficient, effective and equitable).

Public Surveys Expose the Disconnect between Perceived Contaminant Sources and Water Quality Data in Arequipa, Peru

Gary Vanzin, Colorado School of Mines (A. Malone, G. Romero, P. Garcia, A. Arenazas, J. Ticona, N. Smith, L. Morales, J. Sharp)

Access to safe water remains a challenge in developing countries such as Peru, and the adoption of solutions may be inhibited by economic, technological and social barriers. Here we report on the correlation between residents' perceptions of local river water quality and actual metrics reported by Peru's National Water Authority in the city of Arequipa in Southern Peru. Most of the respondents believed that the Chili River, which flows through Arequipa, contains poor quality water and that it is getting worse with time. A compilation of 692 respondents prominently identified mining as a major contributor to contamination in addition to sewage, litter, and industry. However, water quality data for 2011-2021 indicate thermotolerant coliforms as the primary contaminant, with intermittent spikes above regulatory levels for high pH, chemical oxygen demand, aluminum, iron and manganese. Mann-Kendall trend analysis identified six Chili River analytes that changed over time ($p < 0.05$), with only thermotolerant coliforms posing a health risk. This latter component was surprising in light of the initiation of the Enlozada wastewater treatment plant in 2016. There was a clear degradation in water quality when comparing metrics upstream and downstream of the city, suggesting city-centric pollutant discharge into the Chili River from outside sources such as clandestine sewage release. While residents generally understood that the Chili water was contaminated, there was a disconnect in perception with undue focus on the mining sector that de-emphasized the impact that sewage discharge has on public health. Using these data for public education through awareness programs could yield improved regulation and financing of drinking water, sewage, and drainage services, strengthen the capacities of water professionals in the region, and enhance water conservation.

A Just Transition Towards Regenerative Community Infrastructures

Laura Supple, Colorado State University (M. Arabi)

Modern societies are increasingly confronted by “wicked challenges” resulting from an unprecedented convergence of disruptive forces. Human activities have altered physical environments and ecosystems in nearly every corner of the globe, and quality of life in modern societies is shaped by increasingly complex human-environment interactions and highly uncertain social, technological, and environmental futures. These pressures are reshaping urban life and exposing critical vulnerabilities in engineered infrastructure systems responsible for regulating metabolic flows, guarding against physical and biological hazards, promoting social and emotional wellbeing, and a host of other services underpinning community health and vitality. Engineered to be “fail safe,” gray infrastructure design typically assumes relatively static climatic, demographic, political, economic, and sociocultural operating conditions, resulting in brittle, unresponsive, anachronistic infrastructure increasingly susceptible to catastrophic failure in the face of rapid and unpredictable change. Preparing human society to adapt to and through complex and uncertain futures requires a paradigm shift in how infrastructure is designed, built, and managed to reposition built environments as multifunctional spaces of social and ecological regeneration. Drawing insights from transdisciplinary fields of urban ecology, environmental sociology, and systems science, this research identifies critical flaws in modern infrastructure design and governance that produce and reinforce structural vulnerabilities and inequities across urban landscapes, tracing the origin of these deficiencies to principles of a 20th century design paradigm rooted in logics of extraction and exploitation. We then describe an alternative design paradigm for regenerative social-ecological-infrastructure systems, outlining restorative functionalities needed to initiate and sustain infrastructure transformations towards living systems-of-systems informed by a relational understanding of human-environment interactions. Finally, we lay out a vision for infrastructures that operate as connective tissues of resilient, adaptive communities, and frame a research agenda to address critical knowledge gaps and facilitate community-led transitions to regenerative futures.

Removal of Dyes and Emerging Contaminants by 2-Dimensional Porous Nano-materials

Bhavya Joshi, University of Exeter, United Kingdom (A. M.E. Khalil, S. Zhang, F. A. Memon)

Two-dimensional (2-D) nanomaterials have found their applications in water-treatment, owing to their exceptional specific surface area, and superior biological, mechanical, and physio-chemical properties. However, the reagents used for their synthesis are noxious to human health and hazardous to environment. This study reports on two greener approaches based on “Encapsulation” and “Hydrothermal Treatment”, to the synthesis of graphene and 2-Dnano-sized MoS_2, respectively. Both of the materials synthesised were tested against organic dyes and other emerging contaminants and showed 96% Rhodamine-B dye removal and 85% Ciprofloxacin removal. Detailed batch tests were done to examine the effects of adsorption time, adsorbent dosage, solution pH and temperature. Adsorption mechanism was also investigated via thermodynamic calculations, adsorption kinetics, and isotherm modelling. The results indicated that both of the as-prepared 2-D nanomaterials could be potentially used as promising adsorbents for removal of organic pollutants from waste-water.

Evaluating the Impacts of Cattle Grazing Management on the Water Quality of Surface Runoff in Central OK

Austin Phillippe, Oklahoma Water Resources Center, Specialty Researcher (K. Wagner, R. Reuter, C. Zou, A. Gerhardt)

Water quality impairment of lakes and streams in Oklahoma is often attributed to continuous grazing in riparian zones (Water Quality in Oklahoma Integrated Report, 2020). To enhance water resources, land managers are encouraged to limit cattle grazing in riparian zones and rotationally graze. However, employing these strategies can be cost prohibitive, largely because of the effort and materials associated with physical fencing. Virtual fencing is an emerging technology that could resolve this issue by using GPS-enabled collars to control cattle location. The purpose of this project is to compare water quality between watersheds that are continuously grazed, absent of grazing, or where virtual fencing is used to employ best management practices (i.e., managed grazing of riparian areas and rotational grazing). We are using a paired-watershed approach and non-parametric statistics to evaluate concentration and loading relationships between watersheds for *E. coli*, total Kjeldahl nitrogen, total phosphorus, and sediments. Currently, the project is in phase 1 during which watersheds are continuously grazed at 13.7 acres/cow for the Lake Carl Blackwell (LCB) pasture, 10.2 acres/cow for the East Native (EN) pasture, and ungrazed at the Cross Timbers Experimental Range (CTER). Once sufficient data has been collected on the water quality under continuous grazing, we will implement the BMPs described above and measure water quality responses. This talk will address preliminary results comparing the water quality of surface runoff from the continuously grazed watersheds of phase 1 to the ungrazed watersheds at CTER.

Key Words: *E. coli*, Cattle Management, Virtual Fencing

EPA Project No. MX – 02D00721

Identifying Emerging Wildfire Related Concerns for Water Utility and Water Managers in the Pacific Northwest

Julie Padowski, Washington State University (S. Hall, A. Hohner)

Fire disturbances in the Pacific Northwest (PNW) are projected to increase under a changing climate and are a major cause of increased erosion, runoff, suspended sediment, nutrient release, and debris flows in forested watersheds. This needs assessment study worked with PNW drinking water providers and other water managers whose operations could be substantially impacted by wildfire-related changes to water availability or water quality. Using surveys and focus groups, our goal was to identify what information was needed to improve decision support tools so managers could make more timely and effective decisions about minimizing wildfire-related impacts to water resources. Results from this assessment provided information on the major concerns water utilities and other water managers are facing as wildfires become more common, the strategies they are using to address these challenges, and insights into how better decision support tools could help water managers plan for and deal with wildfire risks and impacts.

Water Quality Impacts of Water and Sediment Control Basins (WASCoBs) in Central Illinois

Sara Lambert, Southern Illinois University

Environmental impacts associated with non-point source pollution originating from agricultural fields have led to an increased need for the implementation of Best Management Practices (BMPs) that can reduce the amount of sediment and nutrient loading to receiving waters. Water and Sediment Control Basins (WASCoBs) and cover crops are both in-field BMPs that have been shown to reduce soil erosion, as well as sediment and nutrients in runoff. While the water quality impacts of each of these BMPs have been studied individually, there is little existing research on WASCoBs paired with cover crops, which was the focus of this study. Four sub-watersheds utilized in this study were: 1) a basin drained by a WASCoB, 2) a basin drained by a WASCoB and planted with a cover crop, 3) a basin drained by an ephemeral gully and planted with a cover crop, and 4) a control drained by an ephemeral gully. Storm event runoff samples from these sub-watersheds were collected and analyzed for total suspended solids (TSS), ammonium-nitrogen, nitrate-nitrogen, dissolved reactive phosphorus (DRP), and total phosphorus. Percent reductions in the basins treated with WASCoBs were determined from nutrient and sediment loading. The sub-watersheds treated with WASCoBs showed a 61-81% lower TSS load, 46-65% lower ammonium-nitrogen load, 80-87% lower nitrate-nitrogen load, 58-78% lower DRP load, and 59-75% lower total phosphorus load compared to the sub-watershed drained by an ephemeral gully. The cover crop treatments did not show a significant impact on water quality, in part due to poor establishment of the cover crop. Reductions in nutrient and sediment loads suggest that WASCoBs have the potential to reduce nutrient and sediment loading in receiving waters, and their continued implementation may help to accomplish water and soil conservation goals.

Evaluating WASCoB's Influence on Water Quality, Phosphorus, and Sediment Trapping

Sierra Mertz, Southern Illinois University Carbondale (J.E. Schoonover, K.W.J. Williard, S.J. Indorante)

Water and Sediment Control Basins (WASCoBs) are used as best management practices that are common throughout southern Illinois. WASCoBs are created both voluntarily and with government assistance. There have been several studies assessing the impacts of terraces and WASCoBs on sedimentation and hydrology; however, few studies have examined nutrient loss. This research project will focus on nutrient loss by sampling water quality and legacy phosphorus from 30 WASCoBs in the southern Illinois region. To assess annual sediment accumulation within the basins, digital surface models (DSM), or 3D maps, are created by flying a drone equipped with a 4K camera to determine changes in elevation. The images are then processed in Pix4D to render a point cloud, which in return creates the DSM. To assess the drone accuracy, ground truthing is implemented by placing feldspar pads to assess the quantity of sediment deposition in the basins. The basins are soil sampled to determine the amount of nitrogen and phosphorus accumulation. Each time there is a significant rain event, water samples are collected from a subset of basins, from the lowest elevation point and the tile line. Total suspended solids, nitrogen, and phosphorus analyses are preformed to determine the difference between the water entering the basin compared to that leaving the basin (i.e., inflow vs. outflow). These data will provide evidence to help guide the Illinois nutrient loss reduction strategy that is aimed at reducing nitrogen and phosphorus runoff into water ways.

Water Footprint Assessment of Water Sensitive Urban Design Plans to Meet the Challenges of Climate Change

Rashid Farooq, Swinburne University of Technology

Water systems developed usually with little holistic considerations to ecological, hydraulic, hydrologic, water quality, and economic impacts. Due to the persistent pressures that continuing urbanization and climate change exert on our urban systems, the emergence of water sensitive urban design (WSUD) approaches were inevitable. Accordingly, the situation now demands for a fundamental change in the way the efficiency of an urban water infrastructure is being assessed, which must include the tracing of water footprint to ensure the most efficient use of this limited natural resource. Current study reveals that water footprint is an indicator of freshwater resources expression, measured in terms of amount of water consumed or polluted. A detailed water footprint accounting has been carried out by input-output analysis of water traces considering process analysis of WSUD approaches. The water footprint, in terms of the sum of both direct and indirect water costs of water infrastructure, has accounted. Assessment of blue, green, and grey water footprints as well as the sustainability, efficiency, and equitability of the water footprint have also been assessed. Procedures has been recommended to cover the supply chain of water infrastructures and best practices of WSUD has identified based on resource efficiency. However, the strategic response formulation, which demands an intense resource involvement and multidisciplinary inputs, is beyond the scope of this work.

State of Irrigation Systems in Kansas: Survey Report

Jonathan Aguilar, Kansas State University (J. Thompson)

A road survey of mainly center pivot irrigation systems was conducted in select counties across Kansas between 2020 and 2021. A county road map for the selected counties was divided into three north-south and three east-west transects. The purpose of the survey was to obtain information to characterize the types of center pivot nozzle packages currently in use. Data collected include degree of rotation, number of spans, nozzle type, pressure regulation, general nozzle type, nozzle height, overhang, end gun presence and type, among others. More than 1,600 irrigation systems were visited majority of which are 7-8 spans center pivots with 86% of them equipped with pressure regulators. Natural gas and electric are the two most common power sources and 65% of the systems are likely using GPS in their operation. When compared to the 2003-2006 survey data, in general, irrigators have made improvements that increases the system's efficiency like lowering of the nozzles, increased use of pressure regulators and reduced number of end guns. This information will be valuable in developing targeted extension materials and in designing relevant irrigation research in the region.

Improving Estimates of Corn Evapotranspiration using Remote Sensing-based Crop Coefficients

Allan Andales, Colorado State University (E. Costa-Filho, J. Chavez, A. Brown)

Improving irrigation water management through evapotranspiration (ET) based scheduling is key to conserving water resources in agriculture. The objective of this study was to develop a remote sensing based algorithm for estimating actual corn crop coefficients (K_c) and actual ET (ET_a). In situ and satellite data were collected from a furrow-irrigated corn field in northeast Colorado during the 2020 growing season. Stationary and roaming surface temperature data were collected from the field using infrared thermometers and a handheld multispectral radiometer, respectively. Surface reflectance data from PlanetScope Dove microsatellites were used along with spatially interpolated surface temperature in the one-source surface energy balance (SEB) approach to obtain remotely sensed corn ET_a. An eddy covariance system in the field provided measurements of observed ET_a to evaluate the remote sensing-based ET_a modeling approach. The remotely sensed ET_a was used with standardized tall reference ET to estimate actual corn K_c values. These were used to adjust the corn K_c curve in the Water Irrigation Scheduler for Efficient Application (WISE), which estimated daily corn ET_a. The corn ET_a from the adjusted WISE calculations were compared to observed ET_a from eddy covariance. Preliminary results indicated that the SEB approach outperformed the unadjusted WISE K_c approach. The adjusted ET_a from WISE, adjusted with remotely sensed K_c values, showed a 46% error reduction in estimated corn ET_a. This study demonstrated that the remote sensing-based K_c algorithm could potentially improve the accuracy of ET-based irrigation schedulers.

Dynamic Hydro-Economic Optimization Model for Sustainable Agricultural Water Management: A Case Study of Oklahoma Panhandle Region

Yiqing Yao, UC Davis (L. Lambert, L. Levers)

The semi-arid Oklahoma Panhandle region is dominated by row crop productions. Of the total arable land in Texas County, Oklahoma, over 46% is cultivated with wheat, about 20% with corn, and about 15% with grain sorghum. Crop producers in this region rely heavily on the Ogallala Aquifer for irrigation and the water extraction rates have not been sustainable. As a result, producers often face the reduced water table and well capacity, as well as increasing energy consumption and pumping cost. There has been an ongoing quest, among producers and water resource managers in the region, to improve irrigation efficiency and prolong the groundwater life while maximizing the profit of water consumption. This research develops a dynamic hydro-economic model to investigate the optimal cropping pattern and irrigation water application over a 10-year period under various water table targets. Results will be useful for producers and policy makers to better understand the economic importance of sustainable use of groundwater for irrigated agriculture and the need of shifting cropping patterns from more water intensive crops to crops that are more tolerant to water stress.

Linking Irrigation Water Management to Ecosystems Services in a Semi-arid Environment

Abia Katimbo, University of Nebraska-Lincoln

Producers are continuing to pump groundwater for irrigation to sustain their crop yields and food production in semi-arid regions. These regions are however faced with limited water supplies due to persisting drought as a result of climate change. In addition, groundwater resources such as Ogallala aquifer in the great plains region, are experiencing reduced water volumes which has resulted in pumping restrictions and water allocation for irrigated agriculture. The adoption of irrigation water management strategies has the potential to promote sustainable ecosystem services and consequently their derived benefits amidst concerns of limited water availability. For instance, proper irrigation water can contribute to maintaining groundwater quality and quantity for agriculture, human use, and other sectors; as well as maintaining stream flow and enough water supply with good quality at downstream for conducive aquatic ecosystems and recreation, and enhanced growth of vegetation cover for flood control and soil erosion prevention. This presentation will therefore focus on the application of existing and emerging technology in irrigation water management for sustainable and multi-functional ecosystems.

Keywords: Irrigation water management, drought, technology, multi-functional ecosystems.

Sustaining Irrigated Agriculture in the Middle Rio Grande: Insights from Accounting for Climate Change and Agricultural Management Interventions

Ali Mirchi, Oklahoma State University (M. Samimi)

Arid and semi-arid regions with irrigated agricultural activities face dire water scarcity challenges and salinity issues that require adaptation planning. The middle section of the Rio Grande, a transboundary river basin shared by the U.S. and Mexico is a good example. The future of water in this region is complicated by a changing climate, agricultural intensification, growing urban populations, and a segmented governance system. This scenario is being repeated not only in other river basins of the southwestern U.S., but also in other arid and semi-arid regions of the world. Distributed hydrological models have proven to be useful tools to evaluate the climate-related impacts on water quantity and quality, while facilitating assessment of the effects of different anthropogenic activities. This talk will summarize lessons from climate risks for agricultural water availability, and conservation-oriented agricultural interventions in the middle section of the Rio Grande Basin in the U.S.-Mexico border region.

Mismanaging Irrigation because of Heat-related Visual Crop Cues: Evidence from the Mississippi Delta

Nicolas Quintana, Mississippi State University (A. Al-Sudani, D. Gholson)

Irrigation has been a key factor to sustain the ever-increasing levels of agricultural output and productivity across the globe. At the farm level, it is a key tool to alleviate adverse environmental circumstances during the growing season, including soil moisture deficiencies, excessive heat or nutrient deficiencies in some cases. High temperatures associated with soil moisture deficits can limit crop yields. However, these losses are highly dependent on soil moisture conditions that make irrigation a valid tool for preventing, to some degree, heat-related losses. But growers may attempt to reduce heat stress risk by initiating irrigation events even if soil moisture is adequate. Such unnecessary irrigations can exacerbate aquifer depletion in regions that depend on groundwater for irrigation such as the Delta region of Mississippi. This is particularly concerning in light of expected changes in climate that will challenge irrigated agriculture and put further pressure in agricultural regions that are relatively rich in water. Because only a small fraction of rainfall occurs in the growing season, producers in the Delta rely on irrigation to maximize crop output; and the Mississippi River alluvial aquifer (MRVAA) is their primary water source. The resulting groundwater demand (more than 370 million m^3 annually) exceeds the rates of recharge in most areas and induces the depletion of the MRVAA at an approximate annual rate of 30.5 cm. The untimely depletion of the MRVAA imposes significant economic losses that are not immediately evident to producers. Analysis of field-level water use data, enriched with weather and agronomic variables; indicates that growers apply additional irrigation water in periods of extreme air temperatures, regardless of soil moisture content. Our preliminary results suggest a lower-bound volume of groundwater overdraft of nearly 280,000ML (over 226k acre-ft.) across the Delta.

Examining the Right-of-Way Process for Navajo Nation USA Indian Allotment Lands in Connection to the San Juan River and the Navajo-Gallup Water Supply Project

Participatory Session led by Bernadette Romero-Benally, New Mexico State University

Today, there are 573 Indian nations across the USA. Each nation has its own history to Indian allotment lands and Indian water rights. This research examines the administrative Right-of-Way process for the Great Navajo Nation allotment lands and applying it to a real example, the Navajo-Gallup Water Supply Project. A Project that was approved by a recent Navajo Nation San Juan River Water Rights Settlement. A Project that involves two federal sister agencies and Navajo allottees. The Project's Right-of-Way process is initiated by the Bureau of Reclamation through the Bureau of Indian Affairs, who will either approve or disapprove the Right-of-Way easement.

What is a Right-of-Way? What are Indian allotment lands? What is the Navajo Nation San Juan River Water Rights Settlement? What is the Navajo-Gallup Water Supply Project? How do these four concepts influence one another? The examination began by working with the Bureau of Reclamation, the Bureau of Indian Affairs and the Navajo Nation affected by the Project. One research finding is that the Bureau of Indian Affairs has the authority over the Navajo allotment lands, not the tribe. Another finding, it is written in the Settlement that the Navajo water rights was settled as a whole tribe, not individually.

We learned that the current Right-of-Way process for the Navajo allotment land is quite general. We learned that the Project pipeline alignment will cross six types of land status. Each type has its own Right-of-Way process. Lessons learned from this research has the potential to guide policy makers, the Secretary of Interior, nations, tribes, and pueblos, tribal leaders, Indian allottees, and economic developers about the Right-of-Way issues found on Navajo allotment lands. One leading Right-of-Way issue is retrieving the Right-of-Way consent signatures from the Navajo allottees. Today, there are more and more Indian water right settlements being settled across the USA. For future Indian water rights settlement, it is the recommendation of this research to carefully address and include a Right-of-Way process for Indian allotment lands and to settle water rights for individual Indian allottees. Indian water rights should be quantified individually as a property right, not as one entire tribe.

This session will be a brief presentation followed by the Navajo-Gallup Water Supply Project (the Project) Game. This is a game about building the Project pipeline. There will be upside cards placed in a straight line and the participants each pick a card, to determine the fate of the pipeline. The game shows participants the challenges faced by the Bureau of Reclamation to build the pipeline. Examples of challenges the Project alignment faced are the different types of land status, findings of cultural resources, and funding sources.

Community Response to Floods in the Cache River Watershed of Southern Illinois: Application of a Proposed Framework for Assessing General and Specified Community Resilience

Raymond Bieri, Southern Illinois University Carbondale (K. Akamani)

Recent years have seen increased awareness about the potential adverse impacts of climate change on hydrologic systems and human communities. The concept of community resilience – the capacity of communities to respond to drivers of change in a manner that maintains or improves upon community well-being – is widely recognized as a suitable framework for informing climate change adaptation policies. Emerging insights from the community resilience literature highlight the importance of the distinction between general resilience, which refers to the resilience of social-ecological systems to all kinds of drivers of change, and specified resilience, which is concerned with the resilience of social-ecological systems to particular drivers of change. While capital assets and institutions are generally considered to be the contextual factors shaping general resilience, the roles of these contextual factors in shaping specified resilience have not been adequately explored. To fill this knowledge gap, we developed a synthesized conceptual model that describes how community capital assets and institutions interact to shape the awareness, motivation, capacity, and opportunities that influence community responses to specific drivers of change. This qualitative study was designed to test the proposed conceptual model by analyzing the responses of two rural communities to floods in the Cache River watershed of Southern Illinois. Data were collected through document review, as well as semi-structured interviews with 23 purposively sampled key informants representing various sectors of the local society. While the data are currently being analyzed with the NVivo software, the results shall speak to key themes in the coding manual, such as perceptions about community assets and institutions, community responses to floods, as well as community awareness, motivation, ability, and opportunities for responses to floods. The results of this study could potentially inform future research and policies on community resilience to floods and other climate change impacts.

Insights and Program Improvements gained from Four Years of SC Adopt-a-Stream's Community Scientist Knowledge and Motivation Surveys

Katie Callahan, Clemson University (E. Anderson)

The SC Adopt-a-Stream (SC AAS) community science water quality and ecosystem monitoring program is five years in operation, with certified volunteers having monitored more than 5500 sampling events at more than 500 sites in SC. Community science in the short-term can increase participants' watershed knowledge and expedite solutions to locally identified water quality and habitat threats. In the long-term, community science programs can democratize scientific data; cultivate a greater engaged and aware community active in creating new social norms for better environmental protection; achieve cost savings with the inclusion of experienced citizen scientists in research projects; increase the diversity and development of underrepresented people in environmental science careers; provide greater insights into interconnected ecological and environmental stressors we face today and in a changed future environment; and so much more.

The SC AAS program has run annual Volunteer Knowledge and Motivation Surveys since 2019, asking certified volunteers questions about what they have learned the most from their involvement in SC AAS; what barriers have prevented them from maintaining their certification or monitoring according to protocols; what motivates them to remain engaged; and where they see themselves as community scientists long-term. Results can be dissected across years and compared across monitoring protocols, of which there are three currently: Freshwater, Macroinvertebrate, and Tidal Saltwater.

Program modifications have occurred in direct response to this feedback, which we believe have strengthened volunteer retention and continued learning. With 96% of 2022 SC AAS volunteer respondents indicating they plan to remain active as SC AAS volunteers for as long as they live in South Carolina, we believe our adaptations are helping us better serve our stakeholders, and thus, better meet our mission as a land grant university. This presentation will review program structure, survey results, and insights learned from these years of IRB-approved survey work.

Irrigator Endowment Effects vs. Non-pecuniary Benefits: Water Market Experiments in Washington State

Suhina Deol, Washington State University (J. Cook)

Water markets in the arid western United States (US) tend to be thin and underutilized. As climate change increases the likelihood of drought across the west, surface water rights trading can help promote efficient water allocation. In this paper, we use an incentive-compatible, induced value field experiment to explore for the first time whether (1) endowment effects or (2) non-pecuniary benefits of farming are increasing the premium that water right owners demand to lease or permanently sell water rights in Washington state. The psychological ownership effect, or feeling possessive of a good, is one explanation for the endowment effect. Large, positive levels of psychological ownership may be present in water rights owners since their identities may be strongly tied to how the water is used, particularly for multi-generational farms. We experimentally induce a psychological ownership effect by asking a randomized subsample of subjects about their own farm "before" we ask them to participate in a valuation experiment and ask another subsample of subjects about their own farm "after" participation in otherwise the same valuation experiment. Non-pecuniary benefits are separate from the endowment effect. Non-pecuniary benefits are any non-monetary benefits that impact a person's lifestyle and increase their general prosperity, which may explain why some people choose to farm even if more profitable opportunities exist elsewhere such as water leasing. We experimentally induce this effect by randomly assigning half the subjects to hypothetically represent owner-operators of a farm, and the other half to represent non-operators who lease their ground (and water rights) to a tenant. In case randomization does not achieve experimental balance, we also observe and control for whether valuation premiums are affected by previous market experience, the characteristics of the subject's real farm, and individual-level covariates.

Urban Irrigable Lands Index (UILI)- Land Use Analysis of Integrated Land and Water Management in the Colorado River Basin

Gretel Follingstad, NOAA-NIDIS-CIRES / The Babbitt Center for Land & Water Policy

The impacts of a decadal scale drought across the Colorado River Basin are reaching a paradox for water adequacy across the basin. This highlights the importance of integrating land use planning with water adequacy to improve water conservation efforts. Yet, the two sectors maintain a significant divide in practice. This gap is fundamentally rooted in institutional processes, regulations, and laws. Drought planning and resilience requires closer attention to the integration of land use planning and water management. This conjunctive approach to long term drought planning includes accounting for projected effects of climate change and aridification from warming temperatures, contributing to increasingly uncertain future water supply.

Outdoor water use is a fully consumptive use, which on average makes up 60% of municipal demand (Beckwith, 2017; Domene & Saurí, 2006b; Mayer et al., 2015; Mini et al., 2014). This research explores specific methods to build a better understanding of potential outdoor water savings, through land use decisions. Specifically, this study provides a foundation for understanding how local level land use and landscape policies can help improve the resilience and sustainability of water resources. This study aggregates the irrigated landscapes of two distinct CRB communities, to estimate potential water savings through landscape design conversion. This analysis demonstrates the potential impact of turf conversion policies or landscape design ordinances, as a mechanism for long term drought planning and water sustainability. This outdoor water use indicator is presented through a geospatial analysis of aerial imagery, parcel data, impervious surfaces and water use. The results show the importance of low water use or xeric landscape designs as a drought planning and resilience mechanism.

NOAA's National Integrated Drought Information System (NIDIS) program promotes awareness and education on the importance of water demand management for drought planning and resilience. This study helps depict the importance of low water use growth patterns for climate adaptation.

Remote-Sensing Satellite Data and Modeling to Inform Intrastate Water Conservation Programs in the Colorado Basin

Organizers: Perry Cabot and John Tracy, Colorado State University

Panelists:

Charlie Ferrantelli, Wyoming State Engineer's Office, Interstate Streams Division
Brenna Mefford, Senior Project Engineer, Wilson Water Group
James Prairie, Hydrologic Engineer, Bureau of Reclamation
Jose Chavez, Professor, Colorado State University

Better techniques continue to be developed in evapotranspiration (ET) modeling through remote sensing, satellite data, and modeling tools. Nevertheless, examples of administrative use of remotely sensed data and ET models specifically in water conservation decision making and implemented programs are limited. This panel session will explore how researchers and water resource managers can collaborate to formally utilize these tools for addressing the pressing problems of the Colorado River Basin, brought on by drought and persistent water scarcity. The purpose of the panel will be to moderate a discussion between leading researchers and water administrators in order to understand the applicability, advantages and limitations of remote-sensing in large-scale conservation programs. As problems on the Colorado River continue to mount, we envision the value of broad spatial ET modeling to increase significantly. Administrators, policy makers and researchers need to establish a more connective dialog to respond more effective and nimbly to the need for planning responses to the Western water crisis.

Quantitative Modelling of the Impacts of Irrigation Water Salinity on Crop Yield and Profitability: Case Study of Groundwater Quality Used for Irrigation in California's Central Valley

Floyid Nicolas, University of California, Davis (T. Kamai, A. Ben Gal, J. Ochoa, A. Daccache, F. Ogunmokun, I. Kisekka)

Salt buildup in the root zone significantly impacts crop yields and profitability. The study incorporated soil variables, climate conditions, irrigation inputs, and economic data to forecast crop yield and profitability for specific crops cultivated in California's Central Valley. Four crops (alfalfa, almonds, table grapes, and processing tomatoes) were replicated under five distinct irrigation water salinity levels (from 0.5 to 5.5 dS/m) and daily irrigation water application rates (from 0 to 12 mm/day). For alfalfa, almonds, grapes, and tomatoes, the goodness-of-fit for relative yield had R^2 values of 0.82, 0.77, 0.78, and 0.64, and RMSE values of 9, 8, 23, and 11%, respectively. While R^2 was 0.99 for alfalfa, almonds, and processing tomatoes and 0.74 for grapes, the RMSE was 48, 211, 2461, and 68 $/ha for alfalfa, almonds, processing tomatoes, and grapes, respectively. The spatial component of the model indicated that Central Valley yield and profits would vary based on soil type and water salinity. At 3 mm/day, no profits were predicted for any crop, while 6 mm/day produced profits of up to $1000/ha for alfalfa and processing tomatoes, and more than 8 mm/day was required for almonds and grapes. This modeling framework can assist policymakers in identifying regions unsuitable for sustainable and profitable irrigated agriculture and prioritizing them for land repurposing with multiple benefits to reduce agricultural water demand and accomplish groundwater sustainability. The model can also be used as a decision-making tool to assist farmers in arid regions in predicting yield loss due to salinity.

Impacts of Soil Health Practices on Soil Moisture Retention in an Arid Agroecosystem

Ibukunoluwa Fademi, New Mexico State University, Department of Extension Plant Science (M. Omer, R. Ghimire, J. Idowu)

Irrigation water availability is challenging in arid agroecosystems, therefore, it is desirable to improve soil health to enhance soil moisture retention. An experiment was set up at the NMSU Leyendecker Plant Science Research Center in Las Cruces, NM, to evaluate the effect of selected soil health practices on soil moisture retention. Treatments included three cover crop treatments: no cover (NC), single cover (SC) [triticale], and multiple covers (MC) [mixture of triticale, barley, Austrian winter pea, and daikon radish]. The tillage treatments included no-till (NT), strip-till (ST), and plow-till (PT), while soil amendment treatments consist of a compost-biochar amendment and no amendment. The amendment treatment was applied in the fall of 2021, while cover crops were planted shortly after the amendment treatment. Field corn (*Zea mays* L.) was planted on the plots after the cover crops were terminated in the spring of 2022 and the tillage treatments established. Soil moisture content was monitored to a depth of one meter in the following increments: 0 – 10 cm (D1), 10 – 20 cm (D2), 20 – 30 cm (D3), 30 – 40 cm (D4), 40 – 60 cm (D5), and 60 – 100 cm (D6). Dynamax PR2 Profiler Probe was used for soil moisture measurements. Results showed that treatment effects on soil moisture were observed during the early stages (V12) of corn growth with NC having higher moisture at D1 – D2 than SC and MC treatments, while NT had higher moisture content than ST and PT at D1 – D3. The amendment treatment did not have a significant effect on soil moisture during the early corn growth and beyond. After the early corn growth stage, the cover crop and tillage effects were mostly not significant on soil moisture contents. Soil moisture will be monitored over more years to assess the long-term impact of soil health treatments in this study.

Quantifying Long-Term Regional Groundwater Quality Benefits from Agricultural Practices

Thomas Harter, University of California Davis (G. Kourakos, C. Henri, Z. Cao, M. Yang)

Groundwater nitrate from agriculture is increasingly sought to be regulated by regional, state, or country agencies. The design of regulatory and other policy programs that aim at improving agricultural practices is driven not only by feasibility and cost of practices, but also by an understanding whether and how much practices may improve groundwater quality. In some jurisdictions, groundwater quality metrics that define "good" or "drinkable" or "sustainable" groundwater quality set the bar for assessing the desirability/permissibility of agricultural practices. Models used in policy- and decision-making can account for the complexity of the agro-environmental system, but also provide a forecasting tool to assess proposed future scenarios. We have developed a nitrate forecasting tool for the 50,000 sq.km Central Valley aquifer system. The aquifer system serves about 10,000 community wells, over 20,000 agricultural irrigation wells, and about 100,000 domestic wells in a region that is predominantly dependent on groundwater for its drinking water. We utilize our recently developed Nonpoint Source Assessment Tool in this Central Valley application (CV-NPSAT). CV-NPSAT extracts a representative steady-state from existing transient subsurface flow models to provide relevant flow fields down to a 10 m scale resolution, then employs an efficient 3D-transport algorithm to hind- and forecast decade- to century scale nitrate dynamics in all wells across the aquifer system. We have validated CV-NPSAT against measured age distributions and against measured history of nitrate pollution in the Central Valley. By combining CV-NPSAT with historic and future scenario field-scale information on nitrate leaching from the root zone, long-term groundwater quality impacts and their spatio-temporal variability are obtained for assessment and evaluation at various spatial scales. Agricultural stakeholders and their regulatory counter-parts employ CV-NPSAT to assess agricultural practices for future outcomes and to constrain the industry toward a suite of practices anticipated to bring groundwater quality into long-term compliance.

Southwest Groundwater and Agricultural Sustainability

Isaya Kisekka, University of California Davis (C. Hillyer, C. Lazcano, F. Ogunmokun, K. Longley, K. Jessoe, M. Nocco, M. Shukla, P. Brown, S. Megdal, S. Ostoja, S. Bradford, T. Harter)

The greatest threat to the sustainability of irrigated agriculture in the U.S. is drought due to climate change, which has resulted in groundwater overdraft as farmers turn to groundwater as an insurance against drought. Some of the most productive agricultural regions in the U.S., such as California's Central Valley are experiencing unprecedented levels of groundwater overdraft. Groundwater is also threatened by salinization and nitrate contamination associated with irrigated agriculture. Sustainable use of groundwater to meet the growing global demand for nutritious food, fiber, and biofuels while ensuring co-benefits for the environment and human health remains a grand challenge. I will present an overview of the activities of the Southwest Groundwater SAS USDA NIFA project being implemented in the Central Valley of California, the Pinal Active Management Area in Arizona, and the Lower Rio Grande watershed, in New Mexico. The presentations will cover a wide range of topics related to groundwater sustainability in agriculture e.g., agricultural managed aquifer recharge (AgMAR), hydrogeophysical mapping of the subsurface to identify recharge sites, groundwater modeling, desalination of brackish groundwater, climate change vulnerability risk assessments, soil health, regenerative agriculture, agricultural water management, nutrient and salinity management, and socioeconomic impacts of groundwater use in agriculture, etc. As well as education and extension initiatives around groundwater sustainability in the Southwest.

Identifying Barriers to Adoption of Cover Crops in the Southern Great Plains

Allen Berthold, Texas A&M AgriLife, Texas Water Resources Institute (S. deVilleneuve)

The Southern Great Plains of Texas and Oklahoma is a semi-arid region, but one of the most agriculturally important areas in the country. The Ogallala aquifer is the primary source of water in the region but the formation that does not recharge at a rate that keeps up with demand; therefore, new approaches to manage aquifer depletion resulting are needed. In the last decade, there have been strong advocates for the adoption of regenerative agricultural practices such as cover crops to reduce aquifer depletion. Limited evidence has been presented by these advocates and benefits of these practices seem to be site specific. As such, research has recently turned its focus to better understand how regenerative practices, such as cover crops, impact soil moisture, impact cash crop yields, etc. In 2020, Texas A&M AgriLife Research received an interdisciplinary grant funded by USDA NIFA to better understand how the utilization of regenerative agricultural practices can enhance agricultural production in the Southern Great Plains of Texas and Oklahoma. The first objective of this project is to gather information from producers and other experts in the region about barriers to the adoption of cover crops, reasons for adopting cover crops, and approaches to overcoming barriers. While we can advance our understanding of the impacts in the field, the data is not useful if we are not addressing key concerns or able to get it in the hands of producers. As such, this information is being gathered to provide critical input to field teams and outreach efforts with the goal of maximizing the distribution of results and possible adoption rates if the practices are beneficial. Preliminary results have thus far rejected our null hypothesis that economics is the primary adoption driver, but final results will be presented.

Climate-smart Agriculture to Conserve Water Resources and Sustain Crop Production in the Texas Rolling Plains

Paul DeLaune, Texas A&M AgriLife Research (S. Ale, E. Kimura, S. Park, Y. Fan)

Degradation of soil resources has rapidly declined in the past century, a time when advances in technology and policy-driven agriculture has led to practices that have reduced many soil and water conservation practices that were once used in ancient agriculture. Conservation approaches such as conservation tillage, crop rotation, and cover cropping are often cited as soil health promoting practices that can restore soil resources and subsequently result in systems that are more resilient. Adoption of conservation practices are below average in the Southern Great Plains, especially for cotton cropping systems. The objective of the work at the Texas A&M AgriLife Research and Extension Center in Vernon has focused on the synergies between conservation agriculture and irrigation management. These studies have been conducted on drip and pivot irrigated systems with evaluation of conservation tillage, crop rotation, and cover cropping. Transitioning to conservation systems in subsurface drip irrigated systems showed that irrigation at 83% ET was within the 95% confidence interval for cotton lint yields. Net returns were also significantly higher for no-till systems (with or without cover crops) compared with conventional till. There were no significant differences in sorghum grain yield between 60% and 90% ET replacement while using notably less water than cotton systems. Over the long-term, no-till systems, with and without a cover crop, had significantly greater lint yields and irrigation water use efficiency than conventional till. Furthermore, inclusion of wheat in no-till increased yields and irrigation water use efficiency with strip-tillage. Applying irrigation water at a critical growth stage proved to be more water efficient than early season irrigation that was used to bank moisture in the soil profile. Compared to no-till over a 6-year average, lint yields were increased by at least 9.5% and net returns were increased by at least 8% when adding a cover crop to no-till under pivot irrigated cotton systems. Delaying irrigation application until critical growth stages, using no-till and cover crops, deficit irrigation, and crop rotation should be considered as best management approaches to conserve water resources while sustaining cotton production in the Southern Great Plains.

Evaluating the Impact of Regenerative Agricultural Practices on Soil Health and Water Quality in Altus, Oklahoma

Jack Edwards, Oklahoma Water Resources Center (K. Wagner, S. Stoodley, A. Mansaray, A. Phillippe, L. Gregory, T. Ochsner)

Agricultural production in the Southern Great Plains region is historically dependent on conventional tillage and mono-cropping systems. These practices can be detrimental to soil health, crop production, and water resources. Regenerative agricultural practices, including the use of cover crops and conservation tillage, have been proposed as an alternative to conventional methods. Desired outcomes from these practices include reduced surface runoff, improved soil health, and improved water quality. The shift to regenerative practices stems from the need to intensify production in an environmentally sustainable manner. Our objective is to test the effects of these practices on total runoff discharge and nutrient content. Runoff from each rainfall event is collected by H flumes equipped with automated samplers that have been setup at twelve edge of a cotton field sites in Altus, Oklahoma. The benefits of cover crops in both irrigated and dryland cotton production systems are cross compared to conventional practices (i.e., no cover crop) in four effective treatments on these twelve half-acre plots. Preliminary results from the first year of this study will be discussed to evaluate the effectiveness of regenerative agriculture on nutrient loading and runoff volume reduction.

Profitability Comparisons of Regenerative Agricultural Practices in Deficit-Irrigated Systems

Donna McCallister, Texas Tech University (B. Guerrero, W. Keeling, A. Wright)

As a result of declining water resources, there is a need to better manage climate-related risk associated with deficit-irrigated and dryland production and to define management options that might improve yield, optimize profitability, increase C sequestration, reduce GHG emissions, decrease climate change vulnerability, diversify producer income streams, and conserve water. Economic budgets will be formed and used to assess the short-term profitability of each regenerative system using management data from field and on-farm trials conducted in Texas and Oklahoma. A risk simulation will be performed using the economic budgets, yield outcomes, weather data, and price conditions to assess the long-term probability that these regenerative systems will provide a positive net return.

A Self-Assessment Framework and Rating System for One Water Cities

Donya Dezfooli, Colorado State University (M. Arabi, J. Bolson, I. Wiersema, M. Sukop, J. (Reed) Mutter, S. Milloning, K. Wamstad)

Urban water systems across the world are plagued by growing social and environmental pressures. Unfortunately, traditional water management systems have been found to be unsustainable. Thus, it is necessary to change the current linear approach dominant in most cities across the world to one that utilizes a high degree of reuse and recycling which is known as “One Water”. Although a handful of frameworks have been developed so far, there is not yet an established self-assessment framework to support the transition to sustainable, resilient, and equitable urban water systems. This study aims to present the One Water Cities (OWC) self-assessment framework with commensurate indicators, metrics, and rating systems to measure progress toward One Water. The proposed framework includes three levels (onboarding, progressing, and advancing) by which cities can assess their One Water strategies, practices, and outcomes against appropriate expectations of performance. These assessment indicators and associated metrics are organized based on the OWC key elements, which represent information gleaned from a broad review of One Water literature, targeted expert interviews with progressive utilities, and a national survey of water stakeholders. Furthermore, the OWC self-assessment framework includes five action categories: One Water Planning, Organizational Culture, Stakeholder Engagement, Informed Actions, and One Water Monitoring, within which clear expectations are defined. These categories enable cities to properly evaluate their progress towards One Water and plan a sustainable path toward the next level. This framework not only enables cities to overcome barriers to One Water and facilitate the long-term transition, but also supports strategic planning and decision-making in response to evolving threats.

Platform Template for Easy Deployment and Operation of Sensors in Support of Water Resources Management Projects

Ciprian Popoviciu, East Carolina University (C. Sawyer, B. Hinckley, M. ODriscoll, R. Etheridge, S. Moysey)

The value of real-time data to water resource management projects has been repeatedly demonstrated in practice and is expected to dramatically increase with the emergence of new types of sensors, with increased sensor densities enabled by lower unit costs and particularly by automated workflows supported by intelligent backends. To materialize the promise of the Internet of Things (IOT), sensors of all types, legacy and next generation need to be easy to deploy and manage. Infrastructures supporting envisioned instrumentation must be flexible operationally and technologically to accommodate the diverse deployment scenarios planed by researchers, educators and professionals. This presentation will describe the architecture, implementation, and use of the Environmental Sensing Data Network (ESDN) developed and operated by East Carolina University (ECU). The ESDN platform is centered around LoRaWAN but it integrates other communications technologies and data sources while facilitating easy integration of various types of water monitoring sensors. ESDN transformed the ECU campus and the hosting city into a lab where new sensors are being evaluated, research projects are conducted, and community projects are facilitated. We will present concrete examples of ESDN helping identify new, low-cost sensors which can dramatically change the economics of water resources management projects. We will also discuss the opportunities offered by the platform to extract insights from and build workflow automation on top of real-time collected data. The footprint of the platform is rapidly increasing across Eastern North Carolina enabling multiple user groups and projects to deploy and manage sensors. We believe ESDN can serve as a template for the cost effective, technologically, and operationally sound deployment of sensor networks in support of water resources management projects.

Characterization of the Relationship between Water Use Intensity and Land Use Planning

Mahshid Mohammad Zadeh, Colorado State University (S. Sharvelle, M. Arabi)

City planners face myriad challenges in providing adequate and sustainable water supply for growing populations in a rapidly changing world. Typically, increasing water demands are addressed by building new water supply infrastructure systems and treatment facilities. However, recent studies show that climate change and extremes may undermine the reliability, resiliency, and affordability of water supply infrastructure. Thus, water demand management, including conservation and recycling, are increasingly relied upon to reduce vulnerabilities to water shortage. This study characterizes the relationship between water use intensity and land use practices in cities within the Front Range of Colorado. Specifically, a cloud-based web tool entitled Polaris is developed that reconciles water consumption data and urban development patterns to provide robust water use projections at the city to regional scales. The tool calculates various water use intensity measures and land use metrics and establishes the patterns in water consumption by land use and economic sectors in time and space. Through robust statistical analysis of historical patterns, Polaris provides water use projections by population and land development while offering capacities to develop scenarios for water use reduction goals by end-use water management in indoor residential, outdoor, and commercial/institutional/industrial (CII) sectors. Furthermore, the tool provides capacities for regional assessment of water use patterns by generalizing land use patterns from multiple water utilities, land use planning, and municipal jurisdiction. The tool has been tested on the water use data collected from four different water utilities within Colorado. This presentation discusses how water consumption and land use metrics quantified within the Polaris tool can be used to make sound water supply decisions at various scales, from city neighborhoods to regional scales, using the results from the analysis of the water utilities data.

Improving SWAT's Irrigation Algorithm to Facilitate Water Management and Conservation in Irrigated Regions

Zaichen Xiang, Oklahoma State University (M. Samimi, D. Moriasi, A. Mirchi, S. Taghvaeian)

Irrigation water allocation, scheduling, and application can change the magnitude of different components of the water budget in agricultural regions. Many physically based hydrologic models, including the soil and water assessment tool (SWAT), simulate the water budget merely in terms of quantity of the applied irrigation water, without capturing the nuances of how different irrigation systems and schedules affect hydrologic fluxes in irrigated agricultural areas. The objective of this study is to develop, incorporate, and evaluate new process-based irrigation algorithms intended to improve SWAT's simulation of irrigation to enable evaluations of scenarios of irrigation water management and changes in cropping systems. New process-based irrigation algorithms will be developed based on existing knowledge of irrigation systems, written in FORTRAN, and incorporated into SWAT2012. The improved irrigation algorithms will be piloted on small (e.g., hydrologic response unit; HRU) and large (HUC-8 watershed) scale to evaluate the impacts of different irrigation technologies and crop production systems on the water budget and water resource sustainability. Improvements in model performance will be documented based on comparisons of streamflow, evapotranspiration, irrigation water application, and recharge obtained using the original and new irrigation algorithms.

Colorado's Agricultural Water Quality Program Outreach and Extension

Christina Welch, Colorado State University, Ag Water Quality Program

Water and soil are critical resources that sustain life. Colorado is both a headwaters state, supplying water to 17 western states and a diverse agricultural state, growing corn, wheat, alfalfa, potatoes, fruits and high-quality hay. Conventional agricultural practices have the potential to degrade water and soil resources, particularly in intensively managed irrigated systems. Primary impacts to agriculture are nutrient and sediment loss from fields, reducing productivity and long-term sustainability. Many producers recognize that conservation practices, often defined as Best Management Practices (BMPs), can not only reduce environmental impacts but also enhance profitability. The Colorado State University (CSU) Agricultural Water Quality Program (AWQP) develops, demonstrates, validates, and promotes agricultural Best Management Practices (BMP's) for Colorado producers. These BMPs target methods to minimize the impact of fertilizer and pesticide applications on Colorado's water resources to the extent technically and economically feasible. The AWQP work includes research and outreach addressing diverse issues such as; nutrient management, agronomics and economics of conservation tillage, filter strips, Internet of Things (IoT) low-cost technology, private well and septic educational materials and more. To improve the program's impact, outreach work focuses on an irritative cycle of communication and support from commodity groups, independent crop consultants, individual producers, and state and national regulators. The AWQP continues to adapt as an unbiased science-based program to meet the decision-making needs of producers and policy makers in Colorado.

Improving Surface Water Quality in Texas through Public Outreach and Education
Leanne Wiley, Texas A&M AgriLife Extension (L. Redmon)

Nearly one-third of waterbodies in Texas do not meet the state water quality criteria, with the majority being impaired due to the elevated E. coli bacteria concentrations. Animal agriculture and feral hogs are potentially significant sources of bacteria in Texas. With nearly 96% of the state privately owned, it is imperative to educate private landowners about the impacts of land management practices on water quality. The Lone Star Healthy Streams (LSHS) program offers Texas landowners a unique curriculum focusing on the best management practices of livestock and wildlife management to reduce E. coli bacteria in waterbodies. This presentation will discuss the purpose of the LSHS course, its application in watershed management, and current and future outreach efforts to continue engaging the diverse landowners of Texas.

Tapping the Well that is Private Property to Address Community-Scale Challenges

Andrea Ludwig, University of Tennessee (C. Scott, J. Berbiglia, N. Bumgarner)

While our communities tackle climate-change accelerated challenges and our ecosystems are suffering vast biodiversity loss, there lies an opportunity to find solutions in the vast resource that is privately held property. Since 2008, the Tennessee Smart Yard program has been delivered through partnerships between Extension and local municipal governments as an education and yard certification program for landowners. Modeled after successful programs in other states in the southeastern United States, the program empowers landowners to take action to protect water and natural resources through nine foundational principles of sustainable landscape management. Once a suite of stewardship practices is adopted by the landowner, then they can certify their yard as a Tennessee Smart Yard. Program delivery has evolved over the past 15 years, developing from the originally conceived workshop-based program to a universally available, fully online program released in 2020, and more recently, to include county-based hybrid approaches. Technological improvements to streamline yard certification have also helped with participation tracking, outcome reporting, and follow-up engagements. Since the release of the online program, the rate of yard certification has been 14 yards per month on average. This presentation will showcase methods used to engage a new audience of virtual learners and share results in terms of practices adopted voluntarily by landowners who are combating climate-changed accelerated challenges and biodiversity loss.

Enhancing Producer Knowledge and Adoption of Irrigation Water Management Practices through Education in the Mississippi Delta

Dillon Russell, Mississippi State University (D. Gholson)

Declining aquifer levels from over-pumping of the Mississippi River Valley Alluvial Aquifer (MRVAA) has served as a catalyst to find ways to improve water use efficiency for producers in the Mississippi Delta region. A recent survey revealed that producers in the Mississippi Delta region do not believe there is a groundwater issue, which is one reason why this problem persists. The Mississippi Master Irrigator Program is being developed to raise awareness of groundwater issues and to facilitate the adoption of irrigation water management practices. This program is modeled after the award-winning Master Irrigator Program from the North Plains Groundwater Management District in Dumas, Texas. Our program differs slightly in that we are delivering the course through a hybrid approach consisting of online modules and in-person training. Prerequisite online modules of video instruction are currently being developed by MSU Extension specialists, as well as other private individuals/entities in the region with specialized expertise in the following topics: soil health, agronomics, irrigation scheduling, irrigation systems and equipment maintenance, the economics of irrigated agriculture, policy and management. The online portion of this course will launch once the online modules are complete. Program participants will be required to complete the prerequisite modules to become eligible for the in-person training and demonstration activities. As content develops, more information regarding the program and dates will become available. This presentation will focus on the development and implantation of a new Extension education program designed to aid in the resupply of the MRVAA through producer awareness and adoption of irrigation water management practices that conserve water and maintain or improve profitability.

Blue Carbon and Beyond: Challenges and Opportunities for Landowners

Naveen Adusumilli, Louisiana State University Ag Center

The focus of natural carbon sinks that was traditionally attributed to forests, in recent years, has expanded to consider coastal habitats such as mangroves, tidal wetlands, and seagrass meadows. These habitats play a critical role concerning various ecosystem services and sequester more carbon than the forests. However, coastal erosion losses are substantially impacting these benefits and creating broad economic losses. Louisiana is one such state that has been vulnerable to coastal erosion. Since the 1930s Louisiana lost a total of 2,000 square miles of land area. Against this backdrop, the United States enacted the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) in 1990 to fund coastal restoration projects. Since its inception, 210 coastal projects totaling 100,000 acres have been restored. Similarly, Louisiana's Coastal Vegetative Planting Program, a partnership program between Louisiana Soil and Water Conservation Districts, the Natural Resources Conservation Service of the USDA, and private landowners, helps establish native wetland vegetation on critically eroding wetlands. The USDA, through its Wetland Reserve Easement Program (WREP) within the Farm Bill, supported restoration projects across 11 states totaling 27,000 wetland acres. Although the ecosystem services and the carbon sequestration credits generated from these restored wetlands provide private and public benefits, landowners could often find it challenging to enter the carbon market space as most are uncertain regarding public-private partnerships, and contractual obligations. Local and regional economies might struggle to find financial vehicles to support long-term restoration projects. State and federally funded projects might inadvertently prevent private partnerships. It is critical to discuss these challenges and barriers to landowners and the potential opportunities to develop a much open ecosystem market space.

The Potential of Combining Water Banks with Virtual Water to Increase Water Availability in the Intermountain West

Christopher Lant, Utah State University (R. Rushforth)

Initiated in some western states as early as the 1990s, water banks finesse the legal constraints of prior appropriation by creating a clearinghouse for water sales and leases. They bring to bear many of the advantages inherent in markets by creating transferability and reducing often-prohibitive transaction costs. Senior water rights holders can utilize the opportunities of water banks to sell or lease water. In 2020 the Utah legislature initiated a pilot program to develop water banks with the intended purpose of making the reallocation of water more flexible, while maintaining existing water rights under the prior appropriation system. This well-received initiative comes at a time when drought, climate change, and rapid population increase have conspired to bring Great Salt Lake, Lake Powell, and Lake Mead to historic low water levels. While the U.S. is the largest global exporter of virtual water, internal U.S. transfers exceed the sum of imports and exports by a factor of 18, a quantity of water exceeding the discharge of all North American rivers except the Mississippi. Over 1000 km^3yr^{-1} of water transpired by rainfed crops is available nationally through trade. In 2017 Utah, however, imported 3.59 km^3 and exported 5.20 km^3 of virtual water; the 1.61 km^3 deficit is nearly equal to the annual flow of water to Great Salt Lake. Utilizing the FEWSION database on virtual water transfers among US counties, we compare flows of virtual water to deficits in the Colorado and Great Basins. We explore the transactional environment in which hay and other growers could lease water through water banks and purchase hay from outside these water-scarce basins, thus bringing additional virtual water to the relief of Intermountain West states.

Assessing Stakeholder Perceptions of Water Sharing Arrangements in the South Platte River Basin
Jesse Jo Rego, University of Nevada Reno (L. Singletary, E. Koebele)

In snow-dependent river basins in the arid western US, irrigated agriculture accounts for most freshwater withdrawals, though rapid population growth is increasing urban water demand. In response to these trends, as well as to prolonged drought and aridification of the region, water markets have emerged to transfer water from agricultural to municipal use. Farms and rural areas may face adverse economic and social repercussions from permanent transfers, however. As an adaptation to these traditional water markets, some areas are developing Water Sharing Arrangements (WSAs), which allow agricultural water users to transfer water intermittently or temporarily from agricultural to non-agricultural uses while maintaining their water rights. This study uses semi-structured interviews with stakeholders representing competing water uses in the South Platte Basin in Colorado to assess if and how WSAs can contribute to meeting both agricultural and urban water needs and where improvements can be made. Results suggest that, regardless of water use sector, stakeholders agree that WSAs can enhance opportunities to retain lands for agricultural production while supporting urban development. Further, stakeholders recommend that WSAs be structured to share the costs of infrastructure needed to store and/or move water from rural to urban areas; compensate producers above the value of lost revenue due to smaller yields from reduced irrigation; and increase collaboration and creativity of lease terms to encourage WSA participation. WSAs with these design features may improve overall water use efficiency while avoiding net economic losses, preventing the kinds of negative cultural and ecological impacts that typify buy-and-dry scenarios. These results contribute to extant literature on prior appropriation-based water markets by highlighting stakeholder preferences that can inform the development and use of WSAs.

Assessment of Land Treatment Practices for Reducing Wind-driven Erosion in Rangeland Landscape in the Western U.S. using the APEX Model

Gunho Cho, Texas A&M University (T. Abitew, J. Jeong)

Wind erosion is one of the principal processes of land degradation and dust emission in dryland. Recent climate change trends with increasing climate variability can accelerate the impairment of vegetation communities and topsoil in drylands. The interaction of climate, vegetation community, and soils can cause the negative impact of wind erosion beyond people's predictions. Thus, wind erosion has become a primary concern among agricultural policymakers and scientists. Therefore, developing comprehensive insights into wind erosion modeling enables the assessment of the accurate wind erosion processes using locally specific environmental parameters and climate conditions. An accurate modeling tool serves as a reliable basis for evaluating the effectiveness of best management practices (BMP) for controlling wind erosion. A substantial area of drylands in the western United States, particularly desert rangelands, has suffered a particular level of devastation due to past and present land use, wildfires, and increasing frequencies and durations of drought spells. This phenomenon led to increasing wind-driven soil erosion and land degradation. The main objectives of this study are: 1) to simulate wind-driven sediment transport at three rangeland sites (Jornada, Moab, and San Luis Valley sites) in the western U.S. using enhanced using the Agricultural Policy / Environmental eXtender (APEX) model and 2) to evaluate the effect of rangeland management practices that restore vegetation health and enhance water infiltration on wind-driven horizontal sediment transport. This paper presents the capability of APEX in reproducing wind-driven erosion processes in rangeland landscapes and assesses what-if scenarios related to reducing wind-driven soil losses and landscape restoration.

Keywords: Wind erosion, APEX, LWE, Rangeland

Watershed Protection Plan Improved with Bacterial Source Tracking Data: Adaptability in Implementation

Annalee Epps, Texas A&M AgriLife Extension (T. Gentry)

Watershed protection plan (WPP) educational programs can be recalibrated to meet current needs with bacterial source tracking (BST) data. The Geronimo and Alligator Creeks WPP was developed in 2012 to improve water quality after elevated *Escherichia coli* levels were detected and attributed to nonpoint source pollution. This WPP provided model predictions about potential *E. coli* sources using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). The WPP has since been offering educational programs, cleanup events, and grant-writing support to watershed communities to reduce *E. coli* contamination, with an emphasis on bacterial sources identified with SELECT. From April 2019 to March 2020, a BST project was implemented in this watershed to provide data on current sources of *E. coli*. With this updated information on bacteria in the watershed, the implementation efforts have been adjusted to target the newly identified primary sources of contamination. Educational programs now focus on these sources and updated programs are offered. The watershed coordinator can also assist individuals, cities, and counties to find and acquire relevant grants to address the identified sources of elevated *E. coli* levels. Up-to-date watershed information, particularly bacterial source tracking (BST) data, improves watershed protection plan (WPP) implementation.

Trends in the Eucha-Spavinaw Watershed Show Management Limitations to Reducing In-stream Nutrient Concentrations

Erin Grantz, Arkansas Water Resources Center - University of Arkansas Division of Agriculture (B. Haggard)

The Eucha-Spavinaw watershed spans the Arkansas-Oklahoma border and drains to one of Tulsa, OK's primary drinking water sources. In the early 2000's, a transboundary legal dispute led to strict regulations around nutrient management planning in the watershed. The city of Decatur, AR was further required to upgrade its wastewater treatment plant (WWTP) to meet a reduced discharge limit for phosphorus. Since 2001, the U.S. Geological Survey has operated five gages in the watershed, paired with intensive water quality monitoring. Ten-year trend analysis showed decreases in nutrient concentrations in Spavinaw Creek downstream of the Decatur WWTP inflow, but limited response higher in the watershed where non-point sources (NPS) dominate. Monitoring has continued to present, and in this study, we analyzed the 20+-year record of water quality for trends in nutrient and sediment concentrations using the Seasonal Kendall Test. Flow-driven variability was excluded by analyzing the residuals of LOESS relations of water quality variables and streamflow for trends. Preliminary results suggest that nutrient concentrations still largely have not decreased ($p>0.10$), or may have even increased, where NPS dominates. In contrast, TSS has very likely to likely decreased at all sites, as well as dissolved organic phosphorus (DOP). Recalcitrant in-stream total phosphorus (TP) concentrations at NPS sites are likely due to soils with legacy P supersaturation from decades of poultry-litter applications, as well as stream sediments adsorbing P from runoff. However, the P species profile may be changing, with decreasing DOP as a potential leading indicator for the effects of better nutrient management practices. Initially rapid declines in nutrient concentrations below the Decatur WWTP have leveled off in the last decade. Lagging in-stream nutrient reductions driven by point-source controls suggest that further large P reductions in Spavinaw Creek are unlikely without technological advancement or regulatory promulgation of existing technologies.

Innovative Educational Modules for Sustaining Groundwater and Irrigated Agriculture in the Southwest
Shannon Norris-Parish, New Mexico State University (K. Petty, M. Shukla)

Training an informed and prepared agricultural workforce depends on educational experiences that are supported by real-world solutions. Particularly in STEM disciplines, water issues play a key role in agricultural education. By creating interactive and engaging online modules, our team is focused on creating learning experiences related to groundwater use and sustainability. The modules are designed to be a free resource for secondary teachers to supplement instruction in STEM-related, high school courses. The modules will be organized in three sections: *Groundwater*, *Irrigation*, and *Climate Change.* In the *Groundwater* section, students will learn about the value of groundwater, the types of groundwater, groundwater uses, sources of groundwater, groundwater overdraft, and groundwater contamination. Learning objectives for this section include defining groundwater issues and describing why it is a valuable resource for life, agriculture, and broader industries. In the *Irrigation* section, students will learn about irrigation systems, current irrigation policy, sustainable irrigation, best management practices, and Agricultural Managed Aquifer Recharge (AgMAR). Finally, in the *Climate Change* section, students will learn about topics related to drought, threats to agriculture, impact on groundwater, relationship between conservation and efficiency, and climate adaptation. Each module will be guided by individual learning objectives and will be designed using the Articulate™ Storyline software. To meet these objectives, students will experience a variety of engagement exercises and assessments, such as matching questions, true or false, multiple choice, and short answer. Students will also take short, summative quizzes at the end of each module that will involve a variety of multiple choice, true-false, and open-ended questions. Teachers will also have access to downloadable worksheet material that will be designed to increase comprehension and exposure to each topic. All modules will be open access and hosted on HydroLearn, which is an easily accessible website dedicated to promoting educational resources regarding water issues.

Selecting Cover Crop mixes for Water-limited Environments of Southwestern US

Debankur Sanyal, The University of Arizona (C. Stackpole, S. Megdal)

Commercial growers in the water-limited environments of Arizona are often forced to choose their crops based on water availability and market demands. Very low, erratic, annual precipitation makes it harder to follow traditional conservation practices. Cover crops are an essential soil health tool but producers in the low deserts of Arizona are often unable to grow a cover crop traditionally for green manuring purposes. Majority of producers grow single-species forage crops to satisfy the high demand for livestock feeds, which is economically profitable and helps them continue farming. Additionally, there is a lack of information on which cover crops can survive extreme temperatures in the summer when the farm is growing a winter cash crop or high salt levels in these soils. Therefore, in this study, we use mixes of potential crop species with the intention to examine their performance as potential cover crops for desert environments and also as potential livestock feed. Furthermore, due to low carbon content, most of the traditional soil health indicators are not efficient in gauging soil health improvement following cover cropping. Therefore, our study will analyze soils for multiple soil health indicators such as permanganate oxidizable carbon or active carbon, soil respiration, mineralizable nitrogen, soil protein, aggregate stability, and water holding capacity. Our preliminary analyses show that grass species (millets, sorghum-sudangrass, teff grass) have better survivability in saline soils and/or under higher temperatures than legumes or brassica species. Several cover crop mixes have comparable feed value to the alfalfa hay and can be used for small livestock (goat, sheep) grazing with success. Active carbon and soil respiration values show the potential of certain species mixes to improve soil health, but we will be measuring other soil health parameters to identify the most effective cover crop species.

Streamflow Simulation using SWAT Model for Rio Grande Watershed

Manoj Shukla, New Mexico State University (S. Sharma, 1st author)

The Soil and Water Assessment Tool (SWAT) was used to model the hydrological water balance from the Lower Rio-Grande watershed in New Mexico, USA. The model sensitivity analysis and auto-calibration were performed at the Rio-Grande Conveyance channel at the San Marcial stream gauge with site number 08358300 located in Socorro County, NM. The SWAT model was coupled with the Sequential Uncertainty Fitting (SUFI-2) approach in SWAT-Calibration Uncertainty Programs (SWAT-CUP) package, Watershed systems are simulated by calibrating and validating process-based hydrological models. The PRISM climate group dataset at 4km resolution was used to get the precipitation data of different weather stations in and around the watershed. The objective of this study was to couple the SUFI-2 with the SWAT to improve the streamflow simulation and perform the parameter sensitivity analysis using GSA (global sensitivity analysis) within SWATCUP at Lower Rio-Grande, NM. The SWAT model was used to simulate the stream flow for the Lower Rio-Grande watershed from 1995 to 2000 year period. Based on literature research, 16 parameters were selected from the past for calibration and validation of both the daily and monthly models within SWAT-CUP. The new parameter ranges were imported after several iterations and the calibration outputs from the period showed a good agreement between observed and simulated data with the 500 simulations performed on the daily basis. The Global sensitivity analysis was performed within the SWATCUP and the results show that the parameters like slope length for lateral subsurface flow (SL_SOIL) and SCS Runoff curve number (CN2) are the most sensitive parameters for this basin with the absolute p-value of 0.00 and 0.17 respectively to simulate the stream flow of the lower Rio-Grande watershed. In this study, coupling SWAT and SWAT-CUP improved calibration accuracy and speed by simulating the hydrology within the watershed faster and more accurately.

Exposure to Climate Stressors for California Winegrapes under a Changing Climate

Ning Zhang, University of California Davis (L. Parker, S. Ostoja, I. Kisekka, A. McElrone)

Winegrapes are an economically important crop in California and like all of California agriculture, winegrape cultivation is sensitive to climate change. To assess the degree to which projected future climate will alter winegrapes' exposure to climate-mediated crop stress, this study examines changes in agroclimate metrics critical for winegrape cultivation over key wine growing regions in California. Using the GridMET 4-km gridded meteorological data over the 1991-2020 period and 4-km statistically downscaled future climate data from the MACA v2 dataset over the 2041-2069 period for both RCP 4.5 and RCP 8.5, this analysis calculates changes in metrics including growing degree days, spring frost, and evapotranspiration, as well as extreme precipitation and heatwaves. Varietal-specific thresholds are used to assess the potential implications of changes to these metrics for the 6 most widely-planted winegrape varieties in the state, and results are focused on California's primary winegrowing regions. Finally, given vineyard water use during heat events and vineyard potential to provide soil water storage and/or aquifer recharge during high precipitation events, we conduct two complementary analyses that address both vineyard water use and vineyard water storage capacity under future climate conditions. These complementary analyses highlight the potential challenges and opportunities for California viticulture under climate change and implications for the state's water resources.

Panel Discussion: Overcoming the Challenges of Regenerative Ag Systems in Water-Limited Environments

Organizer: Katie Lewis, Texas A&M AgriLife Research

Panelists:

Katie Lewis, Texas A&M AgriLife Research
Paul DeLaune, Texas A&M AgriLife Research
Kevin Wagner, Oklahoma State University - Oklahoma Water Resources Center
Allen Berthold, Texas Water Resources Institute
Clay Lewis, Producer

The panel will include scientists and producers from Texas and Oklahoma and will elucidate the challenges of regenerative crop production in water-limited environments such as the U.S. Southern Great Plains. Steps to overcome challenges and research being conducted will be the primary focus of discussion.

Water Contaminants: A Potentially Modifiable Risk Factor for Pediatric Cancer in Nebraska

Azar Abadi, University of Alabama at Birmingham

Studies in Nebraska have observed a relationship between estrogen-related cancers and exposure to atrazine in groundwater. However, low groundwater atrazine concentrations in Nebraska were observed in counties with high cancer incidence despite having the highest atrazine application. Our research has demonstrated factors that control groundwater atrazine concentrations are well depth, excessive groundwater abstraction, reduced precipitation, high population, discharge areas, and metropolitan counties. These results demonstrate that low groundwater atrazine may be due to excessive groundwater abstraction accompanied by atrazine. Hence, this makes it difficult to rely on groundwater atrazine measurements as a good predictor for potential health implications of atrazine. Therefore, as we aim to determine the toxicity and health implications of atrazine in this field, groundwater atrazine may not sufficiently explain potential pathological implications; studies aimed at understanding the potential toxicity of atrazine in water should utilize atrazine measurement of already abstracted groundwater.

Human Adaptation to Deteriorating Water Quality from Over-exploited Aquifers

Peter Knappett, Texas A&M University (R. Woodward, G. Carrillo, I. Mendoza, H. Hernandez, Y. Li, P. Farias, G. Miller, J. Hoogesteger, D. Terrell)

In agricultural regions, groundwater pumping drives economic development and growth, however, intensive pumping can cause the water can become toxic for human consumption. We developed a system dynamics model to understand the trade-offs between: 1) agriculture revenue; 2) crop water footprint and price; 3) water quality and population health; and 4) household income. We developed this model for a basin located in northeast Guanajuato State, Mexico. Here toxic concentrations of arsenic and fluoride are produced by chemical reactions promoted by shallow geothermal heat. We modeled the outcome from three pumping scenarios over 100 years; pumping rates were assumed to be increasing (S1), constant (S2) or decreasing (S3). Initially we assumed the average crop value:water footprint ratio of crops grown in the basin in 2020 (0.12 USD/m^3) when we ran the model. Under scenario S1, the depth to water table increased to 426 m. Arsenic and fluoride concentrations increased from 14 to 46 µg/L and from 1.0 to 3.6 mg/L, respectively. The combined estimated IQ point decrements lowered expected incomes in 2120 by 27%. We then calculated the relative difference in Net Present Value (NPV) over a 100-year future time frame in 2020 US dollars. The constant pumping scenario S2 was considered as the baseline to compare to scenarios S1 and S3. Without drinking water mitigation, S1 and S3 yielded a relative NPV of -5.96 x 10^9 and +1.51 x 10^9 USD, respectively. If blanket reverse osmosis (RO) treatment was deployed, however, while keeping pumping constant (S2), the relative NPV was +11.55 x 10^9 USD. Growing higher price, lower water footprint crops, like broccoli (1.51 USD/m^3), increases the revenue generated. The gains to the long-term prosperity of this region from switching to such crops is similar in size to that reported from treating the water for arsenic and fluoride.

Groundwater Resources and Arsenic: Exploring Potential Links between Water Scarcity and Arsenic Concentrations in the San Luis Valley, Colorado

Ryan Smith, Colorado State University (A. Lopez, S. Vajedian, A. Honeyman, S. Fendorf, M. Gribble, K. James)

The San Luis Valley, Colorado has a productive aquifer that provides drinking water to nearly all of the inhabitants of the valley and is also used as the primary source of irrigation for this agriculturally intensive region. Aquifer depletion has been occurring in this aquifer for several decades, and in spite of increase regulation, droughts have resulted in subsidence of up to 1 cm/yr over the past decade. Over 10% of the wells in the valley have arsenic concentrations above the World Health Organization's recommended limit of 10 parts per billion (ppb). Since most drinking water is supplied through private wells that are not monitored for water chemistry or treated to remove arsenic, this poses a serious health risk. In this study, we explore some of the geochemical and anthropogenic drivers for high arsenic concentrations in drinking water in the San Luis Valley. To do this, we use a random forest model that predicts arsenic as a function of multiple predictors including soil chemistry, climate, location, elevation, groundwater altitude, land subsidence and well depth. We find that high arsenic concentrations are driven primarily by high pH, which causes desorption of arsenic from mineral surfaces. Groundwater elevation, which is inversely correlated with groundwater age, was also a significant predictor in arsenic concentrations, with lower groundwater elevations indicating higher arsenic concentrations. Deeper wells, which tend to have older groundwater, were also found to have higher arsenic concentrations. This is concerning because some parts of the SLV are experiencing groundwater decline, which could encourage water users to drill deeper to ensure adequate water supply. Water quality in shallow aquifers is also threatened by fertilizers and pesticides applied on farmlands, providing an additional incentive for private water users to drill deeper for water. Our findings indicate that preservation of high quality groundwater in the shallow subsurface is an important factor in maintaining a source of drinking water with safe levels of arsenic in the San Luis Valley.

Smart Irrigation: Upskilling Our Workforce using an Online Micro-credential, Kit-based Approach for Teaching Irrigation Fundamentals and Internet-of-Things Sensor Technology

Participatory Session led by Jay Ham, Colorado State University (D. Namuth-Covert, A. Andales, N. Clark, K. Enns, J. Zarestky, J. Martin, I. Aksland)

Internet-of-Things (IoT) sensor technology coupled with advances in machine learning could result in widespread improvement in irrigation water management. Irrigation control will likely become more automated by using real-time soil moisture measurements and other data to optimize irrigation scheduling. While many technical innovations are underway, water-related industries cannot take advantage of these developments because the existing workforce does not have adequate training. In a 2021 IoT Signals Report stakeholders listed "can't find resources to help skill up their professionals" as one of the biggest challenges limiting the use of new IoT technologies.

A new grant-funded upskilling program in IoT irrigation technology and Irrigation Principles was developed in which participants earn micro-credentials, much like upskilling “Badging” systems used in the computer industry. Our unique approach includes self-paced experiential, hands-on learning, while still allowing the completion of skill badges using an online, remote-learning format. Currently, a two-badge system is being tested in 20 High Schools across Colorado. The first badge is focused on fundamental irrigation principles and participants use a research-based online irrigation app (WISE) to experience real-world irrigation scheduling. The second badge uses IoT soil moisture sensors that send data to the cloud and post results on the user's custom online dashboard. For the IoT badge, the participants complete exercises using a novel IoT data logger and soil sensors explicitly developed for upskilling at CSU.

This presentation will provide an overview of the upskilling training system. Presenters will demonstrate how the hands-on exercises are interwoven with online content to meet learning objectives. Preliminary data from participating high schools will also be provided. Efforts are underway to extend the upskilling program to adult learners and irrigation professionals in the workforce.

Statistical Investigation of Economic & Climate Signals in Groundwater Data

Zoey Reed-Spitzer and Bonnie Colby, University of Arizona (L. Condon, M. Pereira)

Climatic, economic, and regulatory factors have the potential to influence groundwater conditions. Studies of trends in groundwater levels examine the influences of precipitation, temperature and groundwater pumping. However, groundwater pumping data is not available in many areas around the world. There are political, legal and technical obstacles to requiring and enforcing accurate reporting of groundwater pumping, in many areas of the U.S. and globally. Data on groundwater levels (depth to groundwater) are more widely attainable.

Utilizing groundwater levels instead of groundwater pumping can broaden our understanding of how various factors affect groundwater and guide water management and use decisions. Groundwater is a primary water source in Arizona, where groundwater pumping is regulated and required to be reported only in specific areas -- known as Active Management Areas (AMAs). Preliminary results indicate that economic and climatic factors are statistically significant in econometric models that analyze groundwater levels over time in portions of Arizona's Santa Cruz and San Pedro watersheds. The conference presentation refines these early models and extends them to other areas in Arizona. The statistical models utilize groundwater level data in specific Arizona sub-basins over the period 2010-2022, along with data on climate and regulatory factors and indicators of economic activity over time (such as well counts, housing units, per capita income, and planted acreage). The paper and presentation conclude with key findings and implications of this approach for groundwater management and governance. The research presented represents ongoing federally-funded collaboration among hydrologists and economists across multiple universities.

Past is Prologue: The Effect of Yesterday's Adverse Weather on Agricultural Risk Management Today

Calvin Bryan, Colorado State University (C. Goemans, D. Manning, M. Sloggy)

As participation in the U.S. Federal Crop Insurance Program continues to grow, it becomes more important to understand the behavioral drivers of insurance purchasing decisions. Literature exists regarding how farmers respond to current/planting season conditions; we expand existing work to consider how contemporaneous weather conditions impact not only production outcomes/decisions, but also the producer's decisions regarding how much to invest in risk reduction strategies (i.e., insurance). We also explore the extent to which past weather conditions influence production and insurance decisions. In this research, we construct a unique dataset that links the USDA's Cause of Loss data with the Summary of Business reports at the county and year level, along with several additional county level datasets on weather, the environment, and farm financial characteristics. We focus our analysis on corn producers in the eastern United States, merging in data from NASS on corn prices and planted acres. We then evaluate how the previous year's weather and current conditions affect farmers' decisions related to planted acres, insured acres, the ratio of insured acres to planted acres, liability purchased, and liability purchased per insured acre. Consistent with previous studies, we find that, planting decisions are influenced by weather conditions at the time of planting. We also find that producers insure more when drought conditions exist at the time of planting and/or if extreme drought existed at some point in the previous year. Interestingly, we find that current wet conditions don't impact acreage and insurance decisions, but extensive rain or moisture in the year prior to planting do appear to impact behavior (more uninsured acres and lower insurance levels). This work has important implications not only for the federal crop insurance program, but also for understanding how agricultural producers adjust their risk exposure following adverse climate events.

The Role of Off-season Precipitation and Irrigation Water Use in Groundwater Sustainability

Amer Al-Sudani, Mississippi State University (N. Quintana)

The Mississippi Delta region (MDR) is one of the largest and most diverse agricultural production areas in the United States for commercial crop production such that corn, rice, and soybeans, In addition to cotton, sorghum, wheat, and catfish as well. Water availability in the aquifer has an impact on agriculture land use through allocation of land among different irrigated crops or switching agriculture land from irrigated to non-irrigated production. The MDR receives over 52 inches of rain during the year, on average, but most of that precipitation occurs outside the growing season. Consequently, the region depends on irrigation to sustain agricultural production. According to Mississippi Department of Environmental Quality, from 2000 to 2020 permitted wells increase from about 10,000 to over 22,000 with yearly new permit ranged from 178 in 2003 to more than 1,100 in years 2011-2013. Intensive pumping from the alluvial aquifer has led to declining water levels, which ranged between 2 feet to more than 13 feet from 2000 to 2020. The decline in groundwater level is a consequence of expansions in total irrigated acreage and total water extracted from the aquifer. On the other hand, groundwater levels dependent on recharge from infiltration and percolation of precipitation. Therefore, Precipitation can help to curb the rapid increase in groundwater depletion through decrease water use for irrigation and consider as main source for recharge the alluvial aquifer. This study has two objectives; Objective 1: is to quantify the irrigation decisions at three different margins in response to depth to water and weather condition. Specifically, we aim to examine the following margins response: (i) the number of irrigated acres (extensive margin), (ii) the amount of irrigation applied per acre (intensive margin), and (iii) total water use (total response). Objective 2: is to quantify the impact of total water use and off-season precipitation on groundwater sustainability. Sustaining groundwater levels is a significant policy concern. Results from this study expect to provide policy makers and stakeholders with important insights on the potential unintended environmental consequences of increase in groundwater use for irrigation in the MDR, in addition to the importance of rainfall in sustaining groundwater levels as main source to offset groundwater depletion.

A Spatiotemporal Analysis of Livestock Production in the Texas High Plains and Southern Ogallala Aquifer Depletion

Lal Almas, West Texas A & M University (B. Guerrero, K. Sukcharoen, J. Benavidez)

The Texas High Plains is one of the most prolific livestock-producing areas in the United States. Due to extreme weather conditions and climate change, livestock production in the region may face a severe threat due to declining water availability from the Ogallala Aquifer. The literature shows that few studies have investigated the spatial and temporal pattern for livestock production activities for this region. The main objective of this research is to examine the spatial and temporal changes in raising cattle, beef cows and milk cows in 49 Texas High Plains Counties from the standpoint of localized geographical concentration and spatial autocorrelation. Historical county-level agricultural census data source include National Agricultural Statistical Services (NASS) from 1974 to 2017. Exploratory data analysis (EDA) techniques and the Gini Coefficient were applied to examine the geographical concentration and the spatial dependence of livestock production. GIS-based maps were created to visualize spatial and temporal changes. Livestock commodities examined include cattle weighing 500 pound or more, beef cows and milk cows. Temporal changes results indicate that geographic concentration of the beef cow production is well below the other two sectors. The production of milk cows was most geographically concentrated throughout the study period. The Gini coefficient were computed to analyze the change in geographical distribution. Irrigated cropland acres are needed to ensure supply of feed grains to the growing livestock industry. The percentage of irrigated relative to harvested cropland acreage has decreased over time due to Ogallala Aquifer depletion. In summary, there was a spatiotemporal change in livestock sectors especially milk cows in the Texas High Plains over the study period. Therefore, stakeholders and policy makers have expressed that having information available to them concerning impact of declining Ogallala Aquifer on agriculture and livestock production is important in order to make decisions that sustain the regional economy.

Assessing Indicators of Forest Restoration Success across a Chronosequence of Afforested Cropland in Cypress Creek National Wildlife Refuge

Maggie Herrmann, Southern Illinois University Carbondale (K. Williard, E. Hollzmueller, J. Schoonover, C. Ruffner)

Since 1982, the state of Illinois has afforested over 100,000 acres of abandoned or marginal cropland. Afforestation, the planting of trees on land not in forest cover, is a sustainable forest management practice that has been shown to store carbon, increase plant diversity, improve soil and water quality, and assist in flood abatement. To assess forest restoration success in terms of ecological function, seven ecological indicators were measured across a chronosequence of 50 afforested sites and 20 mature forested sites. Soil indicators: bulk density, aggregate stability, total nitrogen, total carbon, and labile carbon, and vegetation indicators: forest productivity and stocking density were assessed for each site. Additional sampling was completed on 25 nearby agriculture fields for each of the five soil indicators. Our data were analyzed using an analysis of variance test with multiple comparisons to examine differences among indicator values by land use category. Overall, soil indicator bulk density significantly decreased across afforested sites with stand age, whereas indicators aggregate stability, labile carbon, and total carbon significantly increased across afforested sites with stand age. Linear regression analyses were used to assess the change in indicator values with stand age. Additional linear regression analyses were used to assess the change in indicator values with site index, and significant results were recorded for 3 out of the 5 soil indicators. Indicator bulk density displayed a significant negative relationship with site index, and indicators aggregate stability and total carbon displayed a significant positive relationship with site index. Overall, our results indicated that four out of the five soil parameters measured were successful indicators of restored ecological function in afforested sites. Furthermore, we believe that the inclusion of vegetation indices forest productivity and stocking density provides vital information into forest succession and a better understanding of how productive sites benefit soil quality.

Bridging the Gap between Floodplain Management & Watershed Management

Michael Kuitu, Texas A&M University/AgriLife (J. Mowrer)

Floodplain regulations have become widely adopted throughout the United States over the past five decades. In large part, such requirements take the form of ordinances pertaining to development code of engineered structures within mapped floodplains. Seldom included, however, are water quality considerations within flood mitigation provisions. Rather, the primary goals of floodplain development restrictions focus on minimizing financial risk and human peril. Many best management practices are capable of both mitigating flood risk and reducing pollution runoff into surface waterbodies. This presentation details the current floodplain management practices that are prevalent in communities throughout America. Prospective best management practices that may serve to fulfill floodplain ordinances while also protecting or improving water quality will be discussed.

Poor Performance or Indication of Water Losses? Insights into Watershed Structure and Water Losses from Hydrologic Model Simulation across Spatial Scales

Salar Jarhan, University of Wyoming (F. Nippgen, G. Paige)

Hydrologic models are important tools that can aid with watershed management decisions. Increases in human populations as well as declining water supplies caused by drought and climate change make accurate and reliable simulations of hydrologic processes a necessity for sustainable water resource management in the western US. These models exhibit varying degrees of complexity and use different spatial and temporal resolutions. In high-elevation snow dominated watersheds, with complex subsurface geology (e.g., leaky watersheds) it can be difficult to accurately model hydrologic processes. For this study, we use WRF-Hydro, a community-based model developed by NCAR, to simulate discharge in multiple watersheds in southeastern Wyoming. WRF-Hydro combines physics-based and empirical modules to simulate hydrologic processes while integrating both a land surface model (Noah-MP) and atmospheric model (WRF). WRF-Hydro is widely used for modeling hydrologic processes for decision making; the National Water Model for the US uses a configuration of WRF-Hydro. Most applications of WRF-Hydro are performed at larger spatial scales, with small-watershed simulations being largely missing. The goals of this modeling study are twofold. First, we evaluate model performance across multiple spatial scales, ranging from the small-watershed scale (< 1 km2) to regional-scale applications (entire mountain ranges). Within this study, we are assessing potential water losses that can occur at different scales and through different pathways, for example water withdrawals for agricultural applications in the valley and potential deeper groundwater recharge through multiple fault lines running across the mountain range. We address questions on how geological features of a watershed and scale might affect the modeling accuracy in snow dominated southeastern Wyoming. This is an important step to improving water resource forecasts in leaky, snow-dominated watersheds.

Three Rivers QUEST: Success in Collaboration

Melissa O'Neal, WV Water Research Institute (R. Spirnak)

The West Virginia Water Research Institute (WVWRI), a program of the National Research Center for Coal and Energy at West Virginia University, has been actively researching water-related issues since 1967. When municipal water authorities were puzzled by the sudden increase of total dissolved solids (TDS) in late 2008, it was in the interest of WVWRI to find out what might be causing the changes in the water chemistry of the Monongahela River. While numerous programs existed that monitored water quality, the data collected was too sporadic, or the studies did not include TDS. In response to the need for TDS data, routine monitoring on the mainstem of the Monongahela and the mouths of major tributaries began in 2009 with funding through USGS 104b and WVWRI. In early 2010, the coal industry adopted WVWRI's voluntary discharge management plan, resulting in improvements to the Monongahela before it was listed as contaminated by PADEP in late 2010. In 2011, thanks to funding from the Colcom Foundation, WVWRI initiated the Three Rivers QUEST (3RQ) program to monitor the mainstem and mouths of major tributaries along the Allegheny, Monongahela, and Ohio Rivers. In 2014, USEPA used data sets collected by 3RQ to validate the delisting of sulfate contamination in the Monongahela River. Since its initiation, 3RQ has collaborated with various watershed organizations to provide data management through the 3RQs WATERS database and held routine roundtable meetings. Currently, 3RQ GAPS provides monitoring assistance to watershed groups to collect baseline data to secure funding for remediation projects. 3RQ Partners at Duquesne University, West Liberty University, and WVWRI have established partnerships throughout the Upper Ohio River Basin to improve our watersheds.

The Watersheds and Landscapes of the Delaware Basin and Estuary: 2023 Status and Trends

Andrew Homsey, University of Delaware

The Delaware Basin is a watershed spanning nearly 13,000 square miles along the Atlantic seaboard. It is the catchment area for the Delaware River, the longest undammed river east of the Mississippi River, flowing for 330 miles from the Catskills in New York, through four states (New York, New Jersey, Pennsylvania, and Delaware) to the mouth of the Delaware Bay. The basin is home to over 8.5 million inhabitants, and is the drinking water source to millions of additional residents of New York City.

Beginning in 2008 and approximately every five years, a summary of a wide variety of metrics within the Delaware Basin and Estuary (comprising the tidally influenced watersheds in the Basin) has been developed to track the status and trends of a wide variety of watershed metrics.

In 2023 the latest Technical Report for the Estuary and Basin (TREB) was developed by a team of scientists, researchers, and practitioners within the Basin. Major topic areas include Watersheds & Landscapes, Climate Change, Water Quantity, Water Quality, Sediments, Habitats, Living Resources, and Restoration. Here we present a synopsis of several of the metrics relating to Watersheds & Landscape, with a focus on current status and past trends. Metrics include population and demographic trends, land cover and land cover changes, imperviousness, and protected lands. These factors provide a critical backdrop for many of the conditions affecting watershed quality, provision of clean air and water, open space, and overall quality of life to all organisms that rely on the basin to thrive.

Systems Approach to Understanding Human-Water Interactions

Thushara Gunda, Sandia National Laboratories

Water management requires understanding of both natural and social systems, including both hard and soft engineered solutions. In particular, a complex systems approach is required to capture the complex set of interactions (i.e., coupled natural and human system (CNH) interactions) governing water. This talk will highlight how mixed methods, ranging from system dynamics models to natural language processing and machine learning, have been effectively used to characterize water dynamics. These studies highlight the potential for advancing the science of water management across multiple sectors, including food-energy-water nexus. In addition to improving understanding of current systems, such CNH approaches will become increasingly critical as we aim to achieve intersectional goals of water security, carbon neutrality, and resilient energy.

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Key Socio-Institutional Drivers of Human-Water Systems in Western Watersheds

Jamie McEvoy, Montana State University

Understanding and improving the management of human-water systems, or the interactions between humans and hydrology, requires an interdisciplinary approach. Many of our water-related challenges stem from a lack of understanding about the connections and feedbacks between human, natural, and built systems. There are complex interactions and feedbacks between hydro-environmental and socio-institutional factors that affect water availability and vice versa, but most models do not account for these. New paradigms and models that conceive of nature and society as deeply interconnected are needed to achieve sustainability. For example, the hydrosocial cycle and socio-hydrology are frameworks that serve as heuristics for thinking about human-water systems in a more integrated manner. However, more research is needed to improve our understanding of how the various components of the human-water system are interconnected, including improved characterizations of the feedback loops and interactions. Two key socio-institutional drivers of human-water systems in western watersheds are: 1) governance-water interactions and 2) community livelihood-water interactions. This talk will discuss opportunities and challenges for integrating these drivers into models and interdisciplinary research projects.

Simplifying the Complex: Indicators to Characterize Socio-hydrologic Systems

Fabian Nippgen, Department of Ecosystem Science and Management, University of Wyoming (G. Paige)

Improving water availability is one of the key goals in many watershed management approaches. The interactions between natural systems and anthropogenic imprints are crucial for assessing both water quantity and quality, especially in areas that experience pressures from growing populations. The fact that many US states that experience large populations gains are located in arid or semi-arid climates exacerbates the problem, not even considering uncertainty in future water supply from climate change. Hydrologic models of varying complexity are frequently used to aid and inform management decisions; however, those models often lack the capabilities to simulate the intricate relationships between nature and humans. While the models used certainly need to be adapted moving forward, we additionally suggest an indicator-based approach to better understand these socio-hydrological systems. Building on the concept of catchment classification, the idea that watershed processes and functions can be distilled into simple metrics describing hydrologic similarity, we propose an expanded framework that includes both hydrologic and sociologic indicators to describe the coupled systems. We will provide examples of indicators and discuss potential approaches for summarizing these complex and important systems.

Key Drivers of Watershed Biophysical Processes in Western Watersheds

Sam Fernald, New Mexico State University (C. Ochoa, 1st author)

This presentation discusses methodologies and approaches used to assess various ecological and hydrological interactions of cultivated areas and rangeland settings in Oregon, New Mexico, and Chihuahua (Mexico). It encompasses over 20 years working with farmers and ranchers in a variety of land use-environment issues in several climate-representative regions of the North American West, from the arid Chihuahuan Desert to semiarid juniper and sagebrush locations in northern New Mexico and eastern Oregon to the humid environment of the agricultural Willamette Valley in western Oregon. Key drivers of watershed biophysical processes are explored trough the study of soil-plant-water relationships, surface water-groundwater interactions, and land management effects on the overall ecosystem function. Ongoing, long-term, studies with similar assessment and monitoring methodologies offer an opportunity to assess land use-environment relationships by using similar metrics and indicators. For example, through seasonal and inter-annual assessment of soil moisture in the effective root sone, deep percolation, and shallow groundwater relationships. We found that irrigation is an important driver of soil moisture and shallow aquifer recharge in both, the cool-climate (Oregon) and warm-climate (New Mexico), agroecosystems we studied. Irrigation water using flood and sprinkler irrigation methods both resulted in relatively rapid of soil water through the soil profile and into the shallow aquifer. Precipitation, soil water, and shallow aquifer interactions in winter precipitation- dominated (cool climate) rangeland ecosystems showed similarities with irrigated landscapes. However, that was not the case on summer-driven precipitation rangelands. Assessing the impact of environment variables such as precipitation and temperature, and land use practices such as irrigation or conservation practices, on vegetation and water resources across a variety of agroecosystems allows for the identification of key drivers that may be useful to improve land management and inform policy related to agriculture and natural resources.

Effects of Irrigation Methods on Watermelon Production and Water Use Efficiency in the Texas High Plains

Andrea Leiva Soto, Texas A&M University - AgriLife Research (Q. Xue, S. O'Shaughnessy, P. Colaizzi, R. Shrestha, F. Workneh, C. Rush)

There are 2.6 million hectares in the Texas High Plains that are irrigated by the water from the Ogallala Aquifer. The decline of the Ogallala water table raises a concern for the sustainability of producing traditional irrigated field crops due to their high-water demand. Thus, farmers are considering alternative crops such as high-value vegetables in their current cropping systems. About 70% of the irrigated cropland uses center pivot systems, which may negatively impact specialty crop quality compared to drip irrigation. Therefore, a field experiment is being conducted to assess the use of Mobile Drip Irrigation (MDI) compared to the Low Elevation Sprinkler Application (LESA) system in center pivots to produce fresh watermelon. Treatments include two methods for irrigation application with different distances between MDI drop hoses, and different estimation methods for water demand. Distances between MDI drop hoses are 15-, 30-, and 60-in (MDI15, MDI30, MDI60, respectively), while LESA hoses have a 60-in distance (LESA60). The different estimation methods for water demand include the Irrigation Scheduling and Supervisory Control and Data Acquisition (ISSCADA) plant/soil feedback system, and a manual irrigation scheduling based on volumetric soil water content measured with neutron probes. Additionally, the ISSCADA plant/soil feedback method was compared to the weather-based irrigation scheduling method for the MDI15 system. We evaluated treatment effects on crop yield, water use efficiency (WUE), yield water productivity (YWP), fruit quality, and crop physiological responses. Based on the field data from the first year, the use of the MDI system resulted in greater biomass WUE, YWP, photosynthesis and transpiration rates, and stomatal conductance compared to LESA. Results of this first year of the experiment suggest the MDI technology is a good alternative for farmers that irrigate with central pivots and that aim to diversify their current cropping system with high-value vegetable crops such as watermelon.

Challenges in Obtaining a Water Budget for a Tailwater System in Sunflower County, MS
Amanda Nelson, USDA-ARS

In the Mississippi Delta region, tailwater recovery (TWR) systems are an important best management practice to address both water quality and quantity issues. TWRs are surface water capture and irrigation reuse systems, using a combination of a ditch to capture surface water, an on-farm storage (OFS) reservoir to store captured surface water, and pumps to move surface water from the ditch into the OFS reservoir and to irrigate nearby fields. To determine if TWR systems are an effective way to reduce groundwater use, a ditch-only TWR system in Sunflower County, MS has been equipped with velocity and flow meters, auto-samplers, level loggers, and rain gauges. The objective of this long-term study is to determine a fully measured water budget for a closed TWR system. This is the first year of the study and preliminary results and challenges encountered will be discussed, with highlights on select storm events.

Effects of Partial Root-zone Drying (PRD) Technique and Strategic Deficit Irrigation on Cotton Yield in Central High Plains

Farzam Moghbel, Kansas State University (J. Aguilar, F. Fazel, K. Koudahe, B. Golden)

The water scarcity in the Central High Plains is a potential threat to the sustainability of the agricultural economy in this region. Practicing deficit irrigation techniques for drought-resistant crops such as cotton could potentially answer this issue. Therefore, field experiments were conducted in 2021 and 2022 to investigate the response of cotton yield (seed + lint) to partial root-zone drying and strategic deficit irrigation techniques in western Kansas. The first two treatments of the study were the application of the fixed partial root-zone drying (FPRD) technique initiated 35 (FPRD1) and 45 (FPRD 2) days before the approximate time of the first growth regulator application. The strategic irrigation treatments were full irrigation, 70% (2022), 50%, and 30% (2022) of seasonal evapotranspiration and also dryland. The highest cotton yield was achieved under FPRD1 in 2021 (260.43 g/m^2) and FPRD2 in 2022 (352 g/m^2). In both growing seasons, the statistical analysis showed no significant difference between the yield under full irrigation, FPRD1, and FPRD2 treatments ($p<0.05$). The dryland condition resulted in 85% and 80% of cotton yield compared to full irrigation condition in 2021 and 2022, respectively. Implementing 50% strategic deficit irrigation did not significantly affect cotton yield in 2021 and 2022 compared to full irrigation conditions. The 70% strategic deficit irrigation treatment caused a 9% reduction in cotton yield compared to full irrigation in 2022; however, this reduction was not statistically significant ($p<0.05$). The results of this study showed that implementing partial root-zone drying techniques and strategic deficit irrigation could be effective irrigation management methods for cotton production in the water-scarce region of western Kansas.

Center Pivot Water Allocation Strategies Under Limited Irrigation

Robert Schwartz, USDA-ARS (A. Domínguez, J. Pardo, H. Klopp, T. Baker, D. Parker, J. Bell, B. Guerrero)

In the southern US Great Plains, groundwater for irrigation is declining because of aquifer depletion and reduced well yield. Under limited irrigation capacities, profitability for maize production can be optimized by allocating available water to a fraction of the pivot area. Irrigation can also be allocated to two crops with differing seasonal water requirements to optimize net returns. In this talk, we discuss the effects of reduced irrigation capacity on yield and allocation decisions for maize and cotton. Under limiting irrigation capacities, crop models must be linked to the spatiotemporal constraints of center pivot water applications to avoid overestimating application depths and simulated yields. Decreases in maize yield associated with limiting irrigation capacities is more pronounced in the Texas High Plains compared with western Kansas; oftentimes declining by more than 50% with a halving of irrigation capacity. Simulations using 25 years of weather data in Bushland, TX show that for a typical irrigation capacity of 7 mm d^{-1} (5.2 gpm ac^{-1}), maximum profitability was achieved by irrigating 75% of the pivot area with the remaining area in fallow or dryland cotton. Concentrating water generated greater net returns because of lower seed and fertilizer costs and 25% greater corn yields that partially compensated for lack of production in fallow areas. Results of the first year of a study examining irrigation allocations within a field planted to an equal area of cotton and maize with a limiting irrigation capacity of 4.2 mm d^{-1} (3.1 gpm ac^{-1}) demonstrated that concentrating irrigation on the maize until August resulted in \$96 ac^{-1} greater net returns compared with a cotton solo crop. In addition, withholding 51 mm irrigation from maize prior to August and applying this amount to the cotton resulted in a 51% reduction in maize yield ($p<0.001$) and a 26% increase ($p=0.047$) in lint yield. Making informed water allocation decisions can permit producers to maintain profitability as groundwater irrigation becomes more limiting. Simulations and fields studies are jointly required to satisfactorily assess allocation decisions and trade-offs to develop decision aids for irrigators.

Improve Yield and Water Use Efficiency in Delayed-planting Corn under Limited Irrigation

Qingwu Xue, Texas A&M AgriLife Research (R. Shrestha, J. Bell, T. Marek, S. Thapa, K. Jessup, C. Naylor)

Corn remains the major irrigated crop in the Texas High Plains and uses 53% of the total agricultural regional water resource budget. However, the declining water table in the Ogallala Aquifer along with recently implemented and future irrigation pumping restrictions will challenge sustainable corn production within the region. As such, research is needed to evaluate and promote management practices to improve corn yields under limited irrigation. The objective of this study was to evaluate the responses of corn hybrids to planting date and irrigation levels. A 2-year field experiment was conducted at Bushland, Texas in 2019 and 2020 crop seasons. The treatments included 4 hybrids, 2 planting dates (mid-May vs. late June), and 3 irrigation levels (100%, 75% and 50% evapotranspiration or ET requirements). The experimental design was a split-split plot design with irrigation level as main plot, planting date as sub-plot, and hybrid as sub-sub plot. Corn was planted at 79,040 seeds per hectare with a row spacing of 76 cm. For both years, irrigation was a main factor for determining the grain yield and hybrid differences were generally smaller than irrigation treatments. Delaying planting date from the middle of May to late June reduced the seasonal crop ET at 75% and 100% ET irrigation levels. Consequently, delaying planting resulted in a greater water use efficiency in corn at 75% and 100% ET irrigation levels. The results of this study showed that delaying planting may provide farmers a strategy to increase or stabilize grain yields under limited irrigation.

Workshop: A Mobile, Hands-On Soil Health Testing Kit for Producers to Increase Conservation Adoption in Semi-Arid Production Regions

Facilitators: Joseph A. Burke, Katie L. Lewis, and Jourdan M. Bell, Texas A&M AgriLife Research

The adoption of conservation management practices in semi-arid regions of Texas and Oklahoma has been limited due to producer concerns about yield declines. Despite these challenges, research has shown that conservation management practices can increase soil properties, potentially decreasing soil erodibility while improving nutrient cycling potential, carbon sequestration, and water storage. To better inform producers and improve conservation adoption, we developed a fully mobile, soil health testing kit that allows producers to evaluate their own soil characteristics. In this workshop, participants will be able to evaluate several soil characteristics with provided samples and gain insight into how these testing kits can increase conservation adoption potential in semi-arid regions.

Panel Discussion: Offering Policy-Relevant Water Resource Economics to Non-Economists

Organizer: Bonnie Colby, University of Arizona

Panelists:
Bonnie Colby, University of Arizona
Mehdi Nemati, University of California, Riverside
Kristi Hansen, University of Wyoming

Economic tools to guide water resource decisions are becoming even more critical given more severe and widespread occurrence of water scarcity. Many water professionals have little background in economics. This session offers perspectives from water economists with a broad diversity of experience offering courses and trainings to non-economists. This session is designed to spark dialogue on: a) most valuable economic concepts and tools for specific audiences, b) teaching techniques that communicate most effectively for various audiences, and c) roles of interactive learning exercises. We also consider the array of benefits from teaching and training non-economists – for those we teach, for addressing contemporary water management challenges, and for our own professional development. The session is structured with brief remarks by the three panelists and ample interactive time to draw upon the experience and interests of those attending. Water and natural resource economists have many opportunities to offer economics to non-economists; in university classrooms and through outreach and public service work with water stakeholders and public agencies. These offerings develop interdisciplinary fluency about economic tools and their value in addressing water resource challenges. The presenters have backgrounds in teaching university resource economics, offering economics as a component of public agency and stakeholder outreach programs, and developing trainings for public agencies, elected officials, non-profit organizations and for professional groups (judges, attorneys and engineers).

Developing a Framework for Implementation of Alternative Water Sources and Water Conservation Practices in Maryland: Integrating Hydrodynamic and Agent-Based Models

Masoud Negahban-Azar, University of Maryland (A. Rahman, A. Shirmohammadi)

Agriculture is the largest water-consuming sector that is responsible for more than two third of the entire freshwater consumption worldwide. With the changes in climate and population dynamics, the requirement for irrigation water is increasing, though the availability of freshwater is decreasing accordingly. To reduce the pressure on the freshwater sources and keep up the productivity of the farms, it is necessary to consider alternative sources of water and implement water conservation strategies. Despite receiving considerable amount of annual rainfall in Maryland, a shifting pattern has been observed in timing and intensity of rainfall (e.g., spring vs. growing season). The main freshwater source in coastal regions of Maryland is groundwater. The changes in rainfall pattern, combined with water demand competition between the urban and agricultural sectors, has resulted in rapid decline in groundwater levels in many regions of the coastal plain. We developed a framework by integrating a hydrological model (Soil Water Assessment Tool - SWAT) and an agent-based model to identify the need and challenges of using recycled water in Maryland and implementing water conservation practices. In this framework, the SWAT model is used to determine and forecast crop water requirements based on long-term climate variability. Additionally, the agent-based modeling system is used to investigate how the adoption of water management strategies emerges because of socio-economic factors and human-environment interactions, and how management policies influence this process. For the initial analysis, two different watersheds (Zekiah and Greensboro Watersheds) in the Maryland area have been selected. Although both watersheds drain into the Chesapeake Bay, they are different in terms of socio-demographical factors, land use, and water demand. Results indicate that differences in these watersheds dictate specific water management strategies based on the soils, land use, and demographics present in each watershed.

The Value of Demand Reduction and Storage Capacity in Alleviating Predicted Water Shortage in Semi-arid River Basins

Ahmed Gharib, Colorado State University (J. Blumberg, D. Manning, C. Goemans, M. Arabi)

Interest in securing reliable water supplies has increased due to climate change and rapid population growth. This challenge is significant in growing areas with limited water supplies. To meet water demands, water managers are considering new storage infrastructure to increase the reliability of water supplies while also identifying opportunities to reduce water use per person. Although these strategies change water consumption patterns, their success at reducing shortages across space and time for different climate change scenarios remains unclear. In this paper, we develop and apply population- and climate-dependent future water supply and demand models, integrate them using a water allocation model, and calibrate it for the South Platte River Basin of Colorado. Then, we simulate the water allocation up to 2100 under eight future climate scenarios and develop a novel approach to generalizing our findings from this model. Results reveal the existence of a threshold ratio of storage capacity to mean water supply above which additional storage has no effect on total water shortages. Hence, areas expected to experience increased water inflows (or those with low current storage capacity) are most likely to benefit from additional water storage infrastructure. This highlights the limitation of storage as a strategy to adapt to decreasing mean water supplies in basins that fall below the threshold. In contrast, demand reduction strategies always reduce expected shortages.

Georgia Flow Incentive Trust: Building from Science and Stakeholder Engagement to Better Drought Response

Mark Masters, Albany State University (K. Rowles, G. Cowie, M. Szydzik)

In Southwest Georgia, the Flint River Basin and the region's aquifers sustain unique natural systems and a robust agricultural economy. However, in some years, drought has caused water scarcity, reduced stream flows and aquifer levels, and created threatening conditions for the farm economy as well as the region's rare aquatic species. During recent droughts, flows in the Flint River Basin have dropped to extremely low levels and threatened the availability of water for aquatic habitat and other uses.

The Georgia Flow Incentive Trust (GA-FIT) is a new project that seeks to restore flows for aquatic habitats while addressing water security for farmers in the region. With a budget of over $50 million, GA-FIT is implementing projects to restore flows for aquatic habitats while addressing water security for farmers in the region. GA-FIT is developing hundreds of new deep aquifer wells to provide alternative water supplies during drought for irrigators that rely on surface water. It is also improving flow augmentation capacity near assemblages of rare freshwater mussels. The project also plans to develop a Habitat Conservation Plan for endangered and threatened freshwater mussels in the region. The project includes a strong stakeholder engagement component to guide implementation. GA-FIT is funded by the Robert W. Woodruff Foundation and a grant from the Governor's Office of Planning and Budget via allocations established from the American Recovery Plan Act for infrastructure development. The GA-FIT partnership is led by Albany State University's Georgia Water Planning and Policy Center.

This presentation will describe how research, data collection, and stakeholder engagement have provided the foundation and stimulus for GA-FIT. It will explain how projects such as the USDA-funded Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) have provided actionable findings and engaged regional stakeholders in collaborative efforts to improve flows and drought response in the region.

A Human-natural Framework for Assessing, Forecasting and Managing Watersheds for Coastal Resiliency along the Gulf of Mexico

Christopher Anderson, Auburn University (K. Dunning, P. Dwivedi, R. Hall, L. Kalin, S. Kumar, J. Lehrter, W. Morse)

Many areas along the northern Gulf of Mexico (GOM) have a distinct land use and land cover (LULC) pattern. Along the shoreline, there is expanding urban development related to population growth and increased tourism. However, immediately inland, land can abruptly become rural where forests and agricultural land cover becomes dominant. These rural lands are important to coastal waters because they represent most of the watershed draining to nearby bays. Current socio-economic and climatic factors are causing many rural landowners along the GOM to reconsider their land use. Future land conversion, particularly the loss of forest cover (natural and managed), may substantially alter the timing and quality of water draining to local estuaries thereby impacting coastal environments and communities. To address these issues, our team devised a coastal human-natural (CHN) framework to examine the potential impact of watershed LULC conversion and climate change on drainage patterns, estuarine ecosystems, and coastal communities. Our work is focusing on two systems along the northern GOM coast: 1) the Perdido-Pensacola Bay system and 2) the St. Andrew-St. Joseph Bay system. We provide a current update to our CHN framework that includes a series of stakeholder surveys, data gathering, and model applications to connect social and environmental factors from watersheds to coastal zones. We review the design and utility of our framework for the purposes of projecting future LULC change (up to 2050) in the focal watersheds along with potential impacts to coastal waters. We also highlight initial results of forest landowner surveys and LULC projections while describing how our framework can be used to address issues of coastal resilience, watershed management, and mitigation for LULC and climate change. Finally, we describe specific applications of the CHN framework designed to assist emerging estuary programs and other stakeholders within our study area with watershed assessment and planning.

The Future of Aquatic Flows in the Anthropocene Epoch

Richard Palmer, University of Massachusetts Amherst (W. Farmer, M. Weiss, M. Rubinstein, S. Carter, J. Valler)

Numerous scientific studies over the past three decades have documented changes in streamflows in our rivers and forecasted continued shifts in hydrology due to climate change. The ongoing, extreme droughts experienced during the last decades in the West demonstrate that water resource systems are being strained in ways that both challenge our ability to meet traditional water resource objectives (hydropower generation, thermal generation cooling, and providing municipal/industrial/agriculture demands) and limit our success at maintaining aquatic flows those that support suitable habitat, stream continuity, biodiversity and the ecological integrity of rivers and streams. Climate change and the extensive development of manmade infrastructure has exacerbated many of the challenges experienced by natural systems, such as habitat fragmentation, variation in the timing and duration of floodplain inundation, shifts in stream temperatures and lake thermal regimes, degraded water quality, altered sediment transport processes, and the conversion of fast flowing steams to lakes and wetlands.

In response, and as part of its mission to foster relevant and translational synthesis, the USGS's National Climate Adaptation Science Center (NCASC) has created a unique program of regional science and national synthesis (noted as the Futures of Aquatic Flows – FoAF) to better understand the potential impacts of climate change on future aquatic flows and to engage natural resource managers in developing adaptation strategies that mitigate these impacts on our aquatic environments. A cohort of nine post-doctoral students, located at the nine regional CASCs, are charged with both creating regionally significant, stakeholder driven science and integrating their results into a national agenda to help water resource decision makes better support instream flow needs.

In this presentation, members of the research team will describe the justification for creating the FoAF program, its relationship to previous USGS CASC research programs, the process for generating a national synthesis project, and opportunities for the community to engage in co-produced, actionable science.

Panel Discussion: The STEPP Initiative: Standardizing Stormwater BMP Efficiency Studies and Implementing a National Verification Program

Organizers: Chris French, Hydro International; Seth Brown, National Municipal Stormwater Alliance

Performance verification programs abound for water management technologies, with groups such as American Society for Testing and Material (ASTM) International, the Underwriters Lab (UL) and the International Association of Plumbing and Mechanical Officers (IAPMO) establishing peer reviewed performance standards, and accredited laboratories independently verifying performance relative to those standards. Compared to other water industry sectors, acceptance of stormwater best management practices (BMPs) is an anomaly. Performance standards and monitoring test protocols are unclear and inconsistent in many states and among academic researchers. While many might follow general guidelines, there has not been one accepted program to provide a baseline standard for how to conduct stormwater BMP performance studies.

Fortunately, there are successful stormwater BMP performance verification efforts underway throughout the country stakeholders and researchers could learn from and partner with. Specifically, the Stormwater Testing and Evaluation for Products and Practices (STEPP) program is being led by the National Municipal Stormwater Alliance (NMSA) to fill the void created by the lack of a national stormwater BMP testing and verification program.

STEPP is currently focused on the ongoing development of performance testing standards for stormwater infrastructure – both proprietary products and public domain practices – based upon existing lab- and field-based protocols. This effort is building on successfully sustained programs like the Washington Technology Assessment Protocol - Ecology (TAPE) and both the New Jersey Corporation for Advanced Technology (NJCAT) verification and the NJ Department of Environmental Protection (NJDEP) certification programs. This work is occurring within the recently established ASTM Committee E64 on Stormwater Control Measures and other NMSA led efforts. With several ASTM standards nearing finalization, including a recently approve trash-capture stormwater BMP test standard, the STEPP program is expected to launch its Phase I verification program in Spring 2024.

Panelists will discuss the need for stormwater BMP verification programs and offer unique perspectives from academia, state regulatory entity, and the regulated private sector. Discussions and audience interaction will allow all to explore the implication of integrating the STEPP framework into state stormwater rulemaking efforts, NPDES stormwater permitting processes, and discuss how academic researchers can further these efforts and provide needed consistency to stormwater BMP studies.

Panel Discussion: East is East and West is West: Interstate River Basin Governance of Drought and Flood in the USA

Organizer: Jerry Kauffman, University of Delaware

Panelists:

Sharon Megdal, The University of Arizona
John Tracy, Colorado State University
Jerry Kauffman, University of Delaware

"Oh, East is East, and West is West, but never the twain shall meet." Rudyard Kipling wrote this about colonialism and the state of world affairs then in 1889 and one could apply it to the affairs of climate and water now in the United States. While the West is coming out of the worst drought in a millennium, the East has been deluged by the floods of Isaias, Ida and now Ian, the worst in centuries along the Eastern Seaboard. While drought and flood are at opposite extremes of the hydrologic cycle, they share common causes that occur in the interstate river basins such as the Colorado, Central Valley, and Missouri out west and the Hudson/Delaware/Chesapeake megabasin back east. This panel seeks to discuss river basin governance models in the United States available to address the common causes of drought and flood. The Eastern Federal-State river basin commissions in the Potomac. Susquehanna, Delaware, and Great Lakes that may hold solutions to address the drought of the hundred-year-old Colorado River Compact. Western basin models in the Colombia and Missouri hold promise to solve the flood concerns that face the eastern river basin states. When it comes to drought and flood, east and west can twain to meet and from this we can learn from each other when it comes to intergovernmental river basin management.

Improved Characterization of Single-family Residential Water Uses with High-resolution Flow Monitoring

Cibi Vishnu Chinnasamy, Colorado State University, Fort Collins, CO. (P. Mayer, M. Arabi)

This presentation will provide important new information on the factors that influence water use. This research, conducted in conjunction with Flume Data Labs, WaterDM, and Colorado State University, characterized single-family residential water uses based on the actual household level end-use and demographic data. Flume has a network of sensors that record flows at high-frequency intervals which enables detailed analysis of water use. The Flume-2 Sensor records water use every 5 seconds, recording up to 17,280 data points in a single day. Flume collects data unobtrusively, directly from the customer water meter. Flume stores and uses this data under the terms of the Flume customer agreement. Customers who install a sensor receive the accompanying Flume app which provides continuous leak detection and leak notifications. Continuous leak notification and detection is a proven approach for finding and reducing customer-side leakage. As a result of this feature, Flume customers are likely to have lower levels of leakage and greater awareness of their overall water use than the general population. As part of the Flume installation process within the Flume smart-Sensor application, the customer is asked to enter information about their home, including number of residents, number of bathrooms, swimming pool - yes or no and type of irrigation system. Additionally, Flume augments these data with property-specific data such as home age, value and size, obtained independently from estated.com. In this study, a multi-regression analysis was conducted using the customer level data along with Flume end-use water data, disaggregated into indoor and outdoor water use. This analysis shows which are the most influential factors in determining lower and higher indoor and outdoor water use including the impact of swimming pools, different lawn irrigation systems or irrigation regimes, property value, home age and size, and more on the quantity of water used for outdoor purposes.

Developing Low-cost, Internet-of-things Sensors for Measuring Soil Salinity: Obstacles, Options, and Opportunities

Jay Ham, Colorado State University (T. Sale, R. Dean, I. Aksland)

Drought, climate change, and the use of reclaimed water is increasing soil salinity in many irrigated systems in both urban and agricultural landscapes. Salinity is more problematic in arid and semi-arid systems, especially as the quality of irrigation water declines. Brine contamination of soils associated with oil and gas production is also problematic. Soil salinity can change rapidly during irrigation and rainfall, or due to leaks and spills in oil/gas production. Thus, managers need real-time data from multiple locations and depths to track and manage soil salts adequately. Unfortunately, monitoring salinity with a proximal sensor is complex, and current commercially available systems can be expensive, hard to use, and challenging to interpret. Monitoring is especially difficult when data are needed over large areas to address spatial variability or to monitor infrastructure (e.g., pipelines).

The objective of this project was to develop and test simple, low-cost sensors for tracking soil salinity. The sensors were designed to be integrated into existing internet-of-things (IoT) soil monitoring systems developed at Colorado State University (CSU). The sensors could also be used for training in a soil sensing educational kit developed at CSU as part of an upskilling program. The salinity sensing electronics were added to an existing soil moisture and temperature sensor developed at CSU. This sensor uses printed-circuit-board (PCB) technology and a high-frequency fringe capacitance measurement to detect moisture. Salinity measurement was added to the sensor platform using several techniques: 1) electrical conductivity, 2) dual frequency capacitance methods, and 3) swept frequency capacitance methods. Sensors were tested in solutions (brine) and multiple soil types over a wide range of salt concentrations representative of agricultural and industrial use cases. Results were compared to lab-based, research-grade instruments and commercially available, proximal salinity sensors. The pros and cons of each experimental sensing technique will be reviewed.

Development and Deployment of Internet of Things (IoT) Sensors in Aquaponics Experiments

Nathan Howell, West Texas A & M University (B. Askarian, M. Ksor)

Aquaponics is the combination of aquaculture, aquatic animal rearing and crop farming, in a common water system. The advantage of such a system is that it requires no soil, uses less water than conventional agriculture, and uses waste nutrients from fish to grow plants. Aquaponics has been in the public consciousness for at least 10 years but is generally perceived as unprofitable and mostly a hobbyist curiosity. In this project, we want to see aquaponics become a more common means of agricultural production in the Texas Panhandle because of its low water use, general sustainability, and high-quality fish-crop production. One way we hypothesize that we might increase profitability is through greater understanding and operational optimization of experimental aquaponics. We therefore developed Internet of Things (IoT) sensors for pH, specific conductivity (SPC), dissolved oxygen (DO), temperature, and nitrate to make such measurement more automatic with higher spatial and temporal frequency in replicate experimental aquaponics systems. Each fully coupled system has an approximate system volume of 300 L, and we examined the growth amount and quality of fish and herb crops for a six-week period with the aim of understanding how the increased data collection might enable higher nitrogen use efficiency (NUE). If this process works well, we will be able to know better how to make AP more profitable through the translation of IoT sensors into a commercial scale operation.

Assessment of Salinity Impact on Agricultural Water Footprint in a Semi-arid Watershed using SWAT-MODFLOW-Salt

Pardis Hosseini, Colorado State University (R. Bailey)

To maintain sustainable crop production and water consumption in the agricultural sector, especially in arid and semi-arid areas, it is necessary to implement management practices to minimize the impact of hydrological and environmental factors. Of the environmental factors that affect agricultural yields adversely, soil salinity impacts agricultural productivity by raising salt ions concentrations in soil water and groundwater in these regions. In order to study how salinity impacts crop production in a semi-arid region, we applied the water footprint (WF) concept using the newly constructed and calibrated SWAT-MODFLOW-Salt hydro-chemical model. The model accounts for the fate, storage, and transport of all major salt ions in the soil profile, aquifer system, and stream network, and in irrigation water diverted either from nearby surface water bodies or from the aquifer. The model was applied to the 732 km^2 irrigated stream-aquifer system within the Lower Arkansas River Valley, Colorado, covering the time period 1999-2009. We calculated the green (WF_{green}), blue (WF_{blue}), and total (WF_{total}) crop production water footprints for major crop types in the area. The study found that on average, 68% of WF_{total} is made up of WF_{green} and 32% is made up of the WF_{blue}. Under salinity stress, the annual average WF_{green} increases by 5.5%, WF_{blue} by 18.2%, and WF_{total} by 23.7%, respectively. The results suggest that salinity has a greater impact on green crop yield compared to blue crop yield. Therefore, policymakers can more efficiently employ water resources and agricultural management practices addressing salinity most importantly in semi-arid agricultural regions.

Collaborative Development of an 'Introduction to Freshwater' Undergraduate Course

Tracy Boyer, University of Wisconsin-Milwaukee (M. Carvan)

Since 2021 faculty from five UW System Institutions (UW-Milwaukee, UW-Madison, UW-Parkside, UW-Oshkosh, UW-LaCrosse) collaboratively developed a foundational 'Introduction to Freshwater' course to be offered at all 13 University of Wisconsin schools. Taught at least once at all 5 schools, the curriculum spans the breadth of basic environmental science and its relevance to water, ecosystems, and society. Nineteen modules in a common Canvas course were created for collaborative instruction using a hybrid of online recordings, simultaneous remote, and in person field trips and class activities. We discuss the challenges of developing common curriculum, student success with engagement and content, and lessons learned. Students were engaged and enjoyed the course as taught at 5 schools. Challenges to the common format were identified such as differing semester length at UW schools, different schedules for both course and instructor, I.e., once vs. Multiple times of week and instructor conflicts for teaching at other campuses, and the target audience at different schools (UW Madison and UWM are targeted to STEM majors, whereas the other courses are more General Education courses by design). However, the flexible nature of the modules allowed for different delivery lengths, instructor styles and strengths, and need for content for majors. Distance and scheduling are challenges to the exchange of instructors teaching their curricular strengths across campuses. Scheduling is also a challenge for scheduling field trips in students' busy schedules depending on nearby availability of resources for field instruction. Students at UWM and UW Madison were largely interested in live, in person instruction, but were on occasion at UWM interested in some online delivery, whereas half of the LaCrosse course was online as a freshman orientation. Instructors so far have had successful engagement with students in hands on learning and with very low stakes assessment in class and through canvas.

CUREs for Water Pollution: Engaging Undergraduates in Water Resources Research

Michael O'Driscoll, East Carolina University (A. Peralta, R. Etheridge, J. Hoben, J. Walker, H. Vance-Chalcraft)

Course-based undergraduate research experiences (CUREs) can reduce barriers to undergraduate participation and build capacity for high impact, collaborative research experiences. These research-intensive practices can also provide opportunities for conducting team-based research in water resources and engage students interested in water resources careers. Over the course of 3-years we implemented multidisciplinary CUREs across geology, microbiology, and environmental engineering courses that focused on local water quality and quantity issues in eastern North Carolina. These courses provided students with research experiences using hydrological, microbiological, and environmental engineering principles to evaluate the effects of land-use on hydrology and water quality and the effectiveness of green stormwater infrastructure to restore stream ecosystem functions. Students learned and applied team science skills to enable collaboration across disciplines through team research projects. Students also learned approaches to apply their classroom knowledge to real-world environmental problems including the impacts of road salting on water quality, the effects of green stormwater infrastructure on nitrogen treatment along an urban coastal plain stream, the effects of sediment deposition on green stormwater infrastructure, and the influence storm events have on the exchange of groundwater and surface water. This course-based undergraduate research approach can contribute to enrollment increases, increased interest in careers in water resources and reduced barriers to research participation. Initial efforts have resulted in over one hundred students gaining water research experience. Additionally, teaching assistants have enhanced their water research and teamworking skills while conducting data analysis to improve understanding of hydrological and biogeochemical processes at active research sites.

Investigating Requisite Professional and Practical Skillset for Workforce Preparedness of Engineering Graduates in the 21st Century Water Industry: An Exploratory Study

Ibukun Osunbunmi, Utah State University (K. Becker, Y. Kim, M. Al Mestiraihi, R. Dupont, D. Stevens)

Education is a tool to prepare students with skillset to achieve development of a society. One of the sustainable development goals (SDGs) is access to clean water and sanitation. However, little is known about the effectiveness of the existing water engineering curriculum in the Middle East and North Africa (MENA) region of the globe in equipping graduates from the water engineering program to address water scarcity and pollution in the area. As part of an ongoing effort to improve the accessibility and conservation of clean water in the region, this study investigates to what extent the current water curriculum adequately achieves the workforce preparedness of its graduates. Five US Universities partners with five Universities in one of the countries in the MENA region with the aim to develop a state-of-the-art water engineering curriculum to solve water problem in the region. In re-evaluation of the existing water program by the US institution, an instrument was developed by experts to identify the most important professional and practical skillsets that graduates from the water engineering program should possess that are requisite for the water industry in meeting this SDGs goal in the 21st century. The instrument measures to what extent students who undergo the existing program possess these skillsets. An exploratory factor analysis was conducted to determine the most important professional and practical skillset that are germane to the water industry, and the factor structure of the construct considered. The outcome of this study is important in redesigning a state-of-the-art curriculum that will prepare future students to possess relevant skills that are needed to function effectively in solving the water crises. The broader impact of this study will help solve the water crisis in this country and serve as a template for other MENA countries that suffer from similar water issues.

City of Wilmington Green Jobs Program

Martha Narvaez, University of Delaware

Today's youth may understand global environmental threats but their connection to their local environment and understanding their role in it is diminishing over time. Schools may teach broader environmental concepts but the value of personal experience in one's local environment is often overlooked or neglected. The City of Wilmington's Green Jobs program seeks to provide urban youth with first-hand and local outdoor experiences while also exposing them to environmental issues, careers, and professional skills. The City of Wilmington's Green Jobs Program was established in 2011. By participating in this program Wilmington's youth can help to transform the city into a greener, cleaner, safer community while experiencing meaningful employment and education opportunities. Candidates must be 14-18 years old and residents of the City of Wilmington. The program is six weeks and the youth work 25 hours/week, earning minimum wage. The Green Jobs Program is led by the University of Delaware Water Resources Center and the City of Wilmington yet is truly a collaborative of environmental nonprofits and government agencies in the state. Interns are hosted by over fifteen different organizations and individuals throughout the six-week program. Program hosts include private consulting firms, universities, nonprofit organizations, and government entities. The program includes field work, exposure to environmental careers and professional development. These include activities such as removing invasive plant species, tree plantings, touring the City's water and wastewater treatment plants, touring engineering projects, engaging with academics and learning about research projects, resume development and recreational activities like canoeing and kayaking. This presentation will discuss how this program began, program logistics, how it has evolved, opportunities and challenges, and future direction and needs.

Farmer Perceptions and Preferences on Conservation Practices and Information Transfer

Dave Spencer, Mississippi State University (J. Krutz, Z. Reynolds, G. Rico Mendez)

Scientists often focus on conceptualizing or identifying conservation practices that elicit a targeted environmental benefit; however, even after discovery of an environmentally sound practice, adoption across the landscape is hindered because researchers do not deliver effective programming. This research is being conducted to identify the socioeconomic and cultural factors that influence the implementation of conservation practices in the Lower Mississippi River Basin (LMRB). A survey instrument was developed and deployed in Arkansas, Louisiana, Mississippi, and Missouri to quantify farmers' perceptions of soil health and water management topics. The survey results are currently being analyzed. Preliminary data reveal that farmers in the LMRB perceive that cover crops improve soil health and microbial activity and diversity while reducing erosion and offsite nutrient transport; however, perceptions surrounding the effect of cover crops on succeeding cash crop yield and profitability is primarily neutral. Contrastingly, farmers perceive moderately positive effects of reducing tillage on yield and profitability while maintaining that a reduced tillage system can also provide environmental benefits. This research also suggests that newer communication tools, such as electronic media, are less desired than traditional "boots on the ground" Extension work. Completed analyses of these results will be presented and prove beneficial to all professionals who communicate with farmers.

Teaching Online with Articulate Storyline

Natalie Carroll, Purdue

Engaging undergraduate students in online learning can be a challenge. Early online formats such as PDF and PowerPoint are static and generally fail to hold students' attention. The presenter will share lectures created in Articulate Storyline©. This software is the leading platform for workplace learning (used by VISA, Google, Microsoft and many others) and received the *Best e-learning Authoring Tool Award* in 2020. It is increasingly used in educational settings.

The Articulate Storyline software provides professional lecture templates, easy incorporation of photo and video, a resource library, closed captions, narration, educator emoji selections, and narration voice choices. This software was first used in 2018 to teach *Environmental Systems Management,* a sophomore-level course, online. Enrollment has increased from 25 students in 2017 to 65 students in 2022. Most of the students are enrolled in the College of Agriculture (with over half from the *Natural Resource and Environmental Science* program). Other colleges served in the last three years include Education, Engineering, Liberal Arts, Management, Polytech, and Science.

The *Environmental Systems Management* course has three major parts: Part 1 introduces, or reintroduces, basic natural resources (soil, water, air quality, and wildlands); Part 2 focuses on Midwestern agriculture and studies the interactions between agriculture and our natural resources; and Part 3 focuses on broader issues – trends in agriculture, federal programs, and related research.

This presentation will introduce the Articulate Storyline software through selected soil and water focused lectures.

Development of Flood Inundation Map using Aerial Imagery, Satellite Data and ICPR4 Expert

Hafiz Ahmad, Florida State University Panama City (W. Vickers)

In recent years, some areas in Bay County, Florida have become vulnerable to flooding. Many residents and businesses have experienced severe flooding in their neighborhoods, especially after Hurricane Michael of 2018. Slight or no rainfall causes inundation in these areas. This study presents a hydrologic model that explores the reason behind this problem. The comprehensive flood inundation model developed for the study integrated the flow simulation of the surface and subsurface region. The dynamic condition of the water table and vadose zone due to infiltration and recharge was incorporated in the model. The model used online satellite-based data and imagery from 2016 and 2022 (before and after Hurricane Michael of 2018) using the 'ICPR4 Expert' program. The results for a storm event on March 31st, 2022 (2.15 inch rainfall during a 2.5 hour duration) was used to validate the accuracy of stream stage in the model with gage station data in the basin area. It was found that this model can accurately predict flood depths. Though the land-cover change in the watershed has some effect, the water table fluctuation in recent years was found to be the most significant factor for flooding in recent years.

Hydrograph Separation Method (HSM) for the Design of Storm Drain Inlets

Walter Silva, University of Puerto Rico at Mayaguez (I. Acevedo)

Urban stormwater drainage systems are part of the urban drainage infrastructure. They encompass the transportation system, structural surroundings, and the topography of the adjacent environment. Adequate stormwater drainage design prevents flooding hazards and protects life and properties. A methodology to improve stormwater drainage design named the Hydrograph Separation Method (HSM) is presented. The Hydraulic Engineering Circular No. 22 drainage manual (FHWA, 2013) defines storm drain inlet efficiency through a series of semi-theoretical equations. Efficiency is the effectiveness of an inlet to collect the discharge along a street gutter as compared with the total discharge flowing on the street. This project used those relations and developed an algorithm that takes the street runoff hydrograph and separates it into intercepted flow by the inlet, and carryover flow bypassing the inlet and continuing along the roadway. The software is written in MS Excel Visual Basic for Applications (VBA). It facilitates the design process of street drainage systems and allows the analysis of different alternatives and how they impact the system's performance. A sensitivity analysis provided additional information regarding individual parameter impact on overall inlet efficiency and flood levels, concluding that longitudinal slopes and cross slopes have the least and most effect respectively on horizontal flow spread and inlet efficiency. With this technique stormwater levels on the streets will be estimated with higher precision and the minor system design will be improved by having better estimates of inlet discharges. Results from the HSM are incorporated in stormwater simulation programs, such as EPA SWMM, for better design of the minor and major drainage systems. Design of low-impact development (LID) measures will benefit from the HSM by having better estimates of flows into areas with vegetation or infiltration sites.

A Generalized Procedure for the Parameterization, Sensitivity, and Uncertainty Analysis of a Small Watershed Scale Hydrological Model

Mahesh Maskey, USDA-ARS, Sustainable Water Management Research Unit (A. Nelson, B. Northup, B. Stucky, H. Huang, D. Moriasi)

Land management for agricultural and livestock production impacts surface and groundwater processes, such as infiltration, groundwater recharge, base flow, and surface runoff. Due to the inherent uncertainty in these processes, researchers have traditionally imparted knowledge of these physical processes through models, from simple to complex. While it can be challenging to determine the appropriate parameter set for a hydrological model, we tested a generalized approach to parameterize hydrological models that require hundreds of physical and empirical parameters. Further, we investigated the potential variability of the model output because of changes in selected parameters by developing detailed sensitivity and uncertainty analyses. To search for the appropriate parameter set, the full range set by the model guidelines are used. Due to the time-consuming nature of parameterization, we also explored using a high-performance computing (HPC) environment in this study. We used the available performance measures and objective functions to find the best parameter set to minimize the disparity between observed and modeled data. To test these parameterization and computing procedures, we modeled cropland and grassland under the grazing operation within the framework of the widely used process-based hydrological model Agricultural Policy Environmental Extender (APEX). Using APEX, we examined the impact of grazing operation in runoff and sediment at the outlet of two fields as part of the Water Resources and Erosion Watersheds, at the USDA-ARS location in El Reno, Oklahoma. This research will help the decision-makers to manage farmland better and open the door to stochastic optimization for many parameters.

Keywords: parameterization, Agricultural Policy Environmental Extender (APEX), croplands, pasture, grazing, high performance computing (HPC) facility

Modeling Investigation of Groundwater Availability in Louisiana and Southwest Mississippi, USA

Shuo Yang, Louisiana State University (F. Tsai)

Considerable groundwater depletion within regional aquifer systems in the U.S. Gulf Coastal Plain has been reported. However, the extent and quantity of depletion and associating impacts on groundwater flow systems and groundwater use remain unclear. This study aims to conduct a groundwater availability investigation that incorporates groundwater stress conditions and storage variations in the Louisiana and Southwest Mississippi area, a part of the U.S. Gulf Coastal Plain. To achieve this, a high-fidelity lithofacies model was constructed to reveal aquifer structures and sedimentary heterogeneity in the Louisiana and Southwest Mississippi area. Based on the aquifer structures, a 3D high-resolution groundwater flow model was built to simulate groundwater level and storage variations under effects of natural processes and anthropogenic activities. The model was calibrated using both in-situ groundwater level data and the Gravity Recovery and Climate Experiment (GRACE) satellite data. A renewable groundwater stress (RGS) index was developed to describe the ratio of groundwater use to renewable groundwater quantity. Preliminary model results suggest considerable cone of depression in heavily developed local aquifers, indicating localized groundwater depletion. However, more significant gain or loss of groundwater occurs in shallow aquifers that connect to major rivers, indicating the groundwater-river interaction is a main driver of groundwater storage variations. The model suggests the Louisiana and Southwest Mississippi area is overall gaining groundwater since 2018. Moreover, the groundwater model suggests critical RGS occurs in industrial and agricultural areas, indicating unsustainable groundwater use. The RGS is also found correlated with seasonal irrigation. This study improves the understanding of regional hydrogeology and benefits effective groundwater management.

Investigating Modeling for the Decline of the Southern Carrizo-Wilcox Aquifer

Jose Garcia, Texas A&M University - Kingsville (M. Alexander, J. Amaya)

The Carrizo-Wilcox aquifer in southwest Texas has been used for many years for agricultural irrigation, including winter vegetable crops in an area known as the Winter Garden region, which consists of the counties: Frio, La Salle, Dimmit and Zavala. According to the Texas Water Development Board, historic well records indicate that groundwater levels have been dropping steadily, with the southwestern portion of the aquifer suffering considerable decline in the last 20 years. In comparison to the pumpage rates of the late 1960s, the demand on the aquifer water has nearly doubled due to industrial usage such as hydraulic fracturing, irrigation for agriculture and potable supply. The Texas Water Development Board has developed a groundwater availability model of the Carrizo-Wilcox aquifer, which contains historic data from well records within the years of 1975 to 1999 and has been used to predict water level trends into the future up to 2050. The purpose of this study is to utilize the existing model from Texas Water Development Board to examine future trends of water availability for irrigation in the Winter Garden region. An updated historic period has been included in the model from 1999 to 2018 within the model runs, and several climate scenarios are utilized in the future input conditions. Two results from the model runs are of great interest and will be included in this presentation. These are the similar characteristics of the downward trends in the aquifer levels from the hydraulic head data for the southwestern portion of the Carrizo-Wilcox aquifer, and at what point will an individual domestic or irrigation wells will run dry when subjected to the aquifer level decline.

The Community-enabled Life-cycle Analysis of Stormwater Infrastructure Costs (CLASIC) Tool

Tyler Dell, City of Longmont (S. Sharvelle, M. Mohammad Zadeh, M. Arabi)

Limited funds require many decision makers in the municipal sector to make difficult decisions in regard to stormwater programs. Communities are trying to receive the most return on their investment in stormwater technologies by selecting technologies that can confer multiple environmental, social and economic benefits. Decision makers must strike a balance between costs, performance, regulatory requirements, co-benefits, and in the case of semi-arid regions, water demands of traditional gray infrastructure and emerging green solutions for stormwater management. The CLASIC tool provides the capability to take into account the costs associated with planning, designing, acquiring, constructing, operating, maintaining, renewing, and replacing stormwater infrastructure. Additionally, the tool compares social, ecological, and economic co-benefits that are achieved by various types of stormwater infrastructure while quantifying hydrologic and water quality performance of the infrastructure. The tool includes capacities to assess the effect of surface vegetations such as trees, land use land cover change, urban growth patterns, climate change, and other factors that influence the performance of gray and green stormwater infrastructure at neighbourhood to city levels. The results are expected to increase confidence in comparing benefits and costs of stormwater infrastructure alternatives based on cost, design, and performance data sets. During this presentation, the modeling framework and applications of the CLASIC tool will be presented.

Estimating Soil Moisture at High Spatial Resolutions Using Meteorological Variables at a Study Region in Northern Colorado

Boran Kim, Colorado State University (M. Bullock, S. Fischer, H. Proulx, J. Niemann, J. Scalia IV, T. Green)

Soil moisture is a key variable for monitoring droughts, forecasting wildfire ignition, maximizing crop productivity, managing grazing lands, and many other applications. Satellites with passive microwave sensors (such as NASA's SMAP satellite) provide soil moisture estimates for most of the Earth almost every day. However, the spatial resolution of these soil moisture patterns is very coarse (9 km grid cells or larger), which limits their use for many applications. In addition, these satellites have limited lifespans and can have interruptions in data provisioning in the case of instrument failure. The objective of this study is to develop and test a soil moisture mapping procedure that produces fine resolution soil moisture maps (10 m grid cells). In this procedure, coarse resolution (4 km) soil moisture estimates are first produced by calibrating an antecedent precipitation index (API) model to the time series of NASA-USDA enhanced SMAP data. This API model also accounts for the recent reference crop evapotranspiration rates. Then, the API-based coarse resolution soil moisture estimates are downscaled to 10 m resolution using fine resolution vegetation cover from Sentinel-2 and topographic data from the USGS National Elevation Dataset (NED). The procedure is tested using a new field dataset from the 4000-ha Maxwell Ranch. The ranch is in the mountains-plains transition in north-central Colorado. The vegetation is primarily herbaceous with scattered shrubs and pine trees. Soil moisture (0-50 mm) was observed using portable HydraProbes at 86 locations as well as a cosmic ray neutron sensing rover on 10 dates during summer 2022. Overall, the proposed soil moisture estimation method reproduces a substantial portion of the spatial variation in the soil moisture observations and consistently outperforms the SMAP input.

Comparative Assessment of Drought Indices in the Upper Colorado River Basin

Mohammad Hadi Bazrkar, Texas A&M AgriLife (J. Jeong)

This study aims to compare different drought indices in drought studies to identify, categorize, and predict drought in the Upper Colorado River Basin (UCRB). The employed drought indices in this study are: Hydroclimatic aggregate drought index (HADI), standardized precipitation and evapotranspiration index (SPEI), standardized melt and rain index (SMRI), standardized precipitation index (SPI), standardized runoff index (SRI), and standardized soil moisture index (SSI). For drought prediction, the widely-used support vector regression is used. First, the drought indices were assessed based on consistency, transparency, validity, simplicity, flexibility, suitability, dimensionality, reproducibility, linkage, sensitivity, and adaptability. Predictability, accuracy, eclipsing, and ambiguity are further used for assessing the drought indices' performances. The leaf area index, as a benchmark that reflects the impacts of drought on vegetation cover, is used to evaluate and compare the performances of drought indices. Overall, based on these criteria, SPEI and SRI were ranked as the most effective drought indices in the UCRB. This study revisits the existing criteria for assessing and comparing drought indices to select the most appropriate drought indices in a specific study.

How Precipitation and Potential Evapotranspiration Drive Modern Drought Trends Relative to a Millennial-length Baseline

Kyungmin Sung, The Ohio State University (J. Stagge)

Understanding current and future drought characteristics is of paramount importance in adapting water resources planning and mitigating potential drought risk under rapidly changing climate. Meteorological drought is often measured by two related indices: the standard precipitation index (SPI) and the Standard Precipitation Evaporation Index (SPEI). Each uses a different meteorological measure: precipitation (P) for the SPI precipitation minus potential evapotranspiration (P - PET) for the SPEI. The use of different drought indices may result in discrepancies in trends, particularly in regions and seasons where the underlying meteorological drivers undergo disparate changes.

In order to better understand these characteristics, this study aims to observe how trends in SPI differ from those in SPEI, ultimately to understand how P and PET drive drought characteristics in different regions. We consider trends at the millennial time scale, spanning from 850 CE to 2100 CE to better evaluate trends within a long-term context. This helps to better understand how anthropogenic impact have shifted SPI and SPEI outside of natural (pre-Industrial) variability. To achieve this goal, we merge modern gridded observations (CRU and GPCC) with Global Climate Change Model (GCM) output from the PMIP4 (850 – 2016 CE), historical (1850 – 2020 CE) and CMIP6 (1850 – 2100 CE) experiments. A novel approach is developed that corrects unique bias in datasets and analyzes non-stationary trends across all datasets simultaneously. This study focuses on observing the state of Colorado, USA, but future work will be expanded to a global scale. This study is intended to expand understanding of climate how change impacts across multiple factors that drive the spatio-temporal variability of drought.

Investigating the Impact of Irrigation Practices on Hydrologic Fluxes in a Highly Irrigated River Basin
Mohammed Almahawis, Colorado State University, USA (R. Bailey, S. Abbas, J. Arnold, M. White)

Irrigated lands are a major source of food production and irrigation practices have significant impacts on water resources and the hydrologic fluxes that control these resources. To better manage water resources and future water supply, the influence of irrigation practices and management on these hydrologic fluxes should be quantified in time and space at varying scales, under the influence of a changing climate and potential irrigation management practices. To fulfill this objective, we use a comprehensive approach to modeling watershed-scale hydrologic processes was applied to the Cache La Poudre River Basin, a HUC8 watershed. A new spatially distributed, physically based groundwater modeling routine, *gwflow* module, that is embedded in the SWAT+ watershed modeling code, was used. Daily water balance in the unconfined aquifer was calculated using a grid of cellular volumes. Major groundwater inflows and outflows include pumping, recharge, groundwater-surface water exchange, groundwater-lake exchange, transfer to soils, and boundary inflow. The *gwflow* module uses national-scale datasets of geologic units, aquifer thickness, streamflow lines, tile drain locations, water bodies, topography, boundaries of cultivated fields, boundaries of HUC12 catchments, and USGS groundwater head data to establish cell-by-cell aquifer properties and spatial connections with SWAT + objects (HRUs, channels, routing units, and reservoirs). A detailed surface and groundwater irrigation routine were added to the source code of the coupled SWAT+*gwflow* module. Moreover, canal seepage was also added to the code.

Retrospective and Statistical Analyses of Agriculture and Groundwater in Arizona through the Lens of Groundwater Management and Access to Surface Water

Danielle Tadych, University of Arizona (M. Ford, L. Condon)

Arizona is an interesting groundwater use and agricultural case study because of its diversity in groundwater regulation, access to surface water, and long history of agriculture despite continuing droughts. Here we present a statistical and spatial analysis of groundwater wells in conjunction with satellite data in order to determine how groundwater storage, drawdown, and drought recovery have changed over time. We also present a retrospective analysis of cropping patterns across the state of Arizona using satellite data from the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). We consider Arizona through two lenses: (1) State regulated or unregulated groundwater use, (2) relative access to surface water sources either directly or by the Central Arizona Project aqueduct. State well and satellite CSR-GRACE datasets are used to determine storage changes and depth to water readings during times of drought. Palmer Drought Severity Index was the drought indicator for correlation analyses and a threshold was set to determine drought severity. Results show drawdown is much greater in areas without groundwater regulation and groundwater dominated regions. Well data indicate areas with access to Colorado river water have better recovery times, but GRACE data show total storage recovery time is getting worse in all areas over time. For cropping analysis, we find irrigated acres statewide have remained consistent from 2008-2020. However, groundwater dominated regions are experiencing increases in acreage of high water use crops, in contrast to surface water dominated regions which have growing acres of low water use crops. We also find that irrigated acres are increasing in unregulated regions while decreasing in regulated regions. Overall, our studies show groundwater legislation and management improves drought resiliency but with surface water cutbacks imminent, the risk of unsustainable pumping or increased fallowing could have profound impacts on the state's economy and groundwater levels.

Sustainability Signaling in Aquifers

Robert Mace, The Meadows Center for Water and the Environment, Texas State University

Many aquifers across the world are produced unsustainably, sometimes purposefully, but many times with ignorance. Many wonder how users could produce unsustainably knowing that, at some point in the future, they will have to reduce their usage. Signaling theory may, in part, explain these circumstances. In signaling theory, one party conveys information about itself to another party. In the case of groundwater, the aquifer (one party) signals the user through its hydraulic response to production by the user (the other party). This hydraulic response may be lowered water levels, decreased springflow and baseflow, and/or land subsidence. Historically, users have not been too concerned with decreased springflow and baseflow since those decreases may be distant to the users' production or may be caused by unassigned collective action.

Signaling can be truthful or untruthful. Aquifers are not, by definition, liars; however, they can be unclear communicators by not conveying actionable information on unsustainable use to users. For example, users are generally focused on their interactions with the aquifer, which is how much they are producing. Declining water levels increase production costs, but if the economic benefit of the water far exceeds the cost of producing it, a producer is unlikely to respond to that signaling. And if water levels decline slowly over time between generations, the sustainability signaling may be hidden. The end result is that the ability to produce a fixed amount of water over a long (multi-decadal) period of time leads users into believing that the aquifer is being produced sustainably. In many highly-responsive groundwater systems, such as small karst aquifers, the sustainability signaling is strong because users cannot maintain their production over the course of years. However, in larger systems, such as the Ogallala and the Carrizo-Wilcox, there is little to no sustainability signaling until well yields themselves decline.

A Sensor-based Peer Learning Agricultural Network for Crop Production and Water Resource Management

Xin Qiao, University of Nebraska-Lincoln (W. Liang, J. Oboamah, A. Gradiz, S. Palle, G. Stone, L. Van Anne, T. Rose)

The Nebraska Panhandle's water resources are key to the region's agricultural productivity. Major crops in the region such as corn, dry edible beans, and sugar beets relies on surface water, groundwater, or a combination of both to reach their target yields. For large-scale water resource studies, remote sensing is frequently used. However, ground truth data are desired and required for validation purposes. In this presentation, we will present a large scale on-farm research, extension, and education network in western NE that is built using IoT-enabled sensors, in-house designed website, and cloud computing technologies. Developed technologies to quantify crop development, such as percentage of canopy cover, will be presented. In addition, we will demonstrate a simple and accurate way to quantify on-farm irrigation events (amount and timing), which is critical inputs for many crop models and water resource research. Lastly, growers' decisions on irrigation management, as well as their adoption of technologies (i.e., soil water sensors) will be discussed. We hope through this presentation, collaborations can be made with scientists in different fields, so tools and technologies can be developed to enhance growers' irrigation management practices, and scientist could have better understanding of growers' practices and its implications on water resources.

Evaluating Demand Management at the Field Scale though Direct and Indirect Measurements of Conserved Consumptive Use

Joseph Cook, University of Wyoming (V. Panhwar, G. Paige, S. Miller, A. Strike, D. Cotterman)

The Colorado River Basin has been experiencing drought for about two decades. The Upper Division States of the Colorado River Basin are collaborating with the Department of the Interior and their stakeholders to evaluate proactive options for protecting critical elevations at Lake Powell while avoiding forced curtailment. A Demand Management (DM) Program, a temporary, voluntary, and compensated program for the reduction in consumptive use is one of the options being evaluated by these States. Determining the feasibility of an Upper Basin DM program requires assessment of many outstanding questions: socio-economics concerns, hydrological effects, and legal frameworks. Critical to a DM program is the ability to measure and/or model consumptive use and the potential conserved consumptive use. Many of the Upper Division states are implementing field investigations to assess our ability to measure and model these processes. In Wyoming, we have initiated a measurement intensive study with the primary objectives to 1) quantify consumptive use under “normal” irrigation practices, 2) quantify changes in consumptive uses under fallow conditions, and 3) document any changes in vegetation characteristics (e.g., species composition) due to fallowing. The study is being implemented on six irrigated fields across the basin, capturing the regional temperature gradient, and include both flood and sprinkler irrigation, and bottomland and upland fields. The 2022 baseline year shows the consumptive use of the study sites during “normal” irrigation practices. An initial comparison of evapotranspiration models has been performed to evaluate consumptive use calculation approaches: OpenET (with an emphasis on eeMetric), Large Aperture Scintillometers, Penmann-Monteith, and Evaporation Pan models. This consumptive use calculation is then complemented with integrated Mike SHE modelling at each study field. The characteristics of these fields will then be used to develop an initial decision model framework, refined by conserved consumptive use’s sensitivity to these characteristics in the integrated modelling.

Rate and Timing Influence Water Use Efficiency in West Texas Row Crops

Glen Ritchie, Texas Tech University (Z. Adene, J. Bicaldo)

Decreased aquifer water in the Texas High Plains has reduced irrigation volume and required most producers to adopt supplemental irrigation strategies. As a result, there is renewed interest in the relative value of irrigation by growth stage in West Texas crops, including cotton and grains. Boll distribution measurements in cotton (*Gossypium hirsutum* L.) can be used to quantify the effects of irrigation on productivity and were used in a studies of irrigation rate × timing in Halfway, TX. Field experiments quantified cotton boll distribution using three in-season irrigation levels (maximums of 0, 3.2, and 6.4 mm d^{-1}) during three different irrigation periods determined by accumulated growing degree days (GDD) based on the threshold of 15.6°C: period 1 (P1, <525 GDD), period 2 (P2, 525–750 GDD), and period 3 (P3, >750 GDD). Combinations of these factors resulted in 27 irrigation treatments, applied with a low energy precision application (LEPA) pivot. This presentation outlines the findings from this work, as well as other high-efficiency irrigation work in the Texas High Plains.

Carbon Footprint Estimate for Irrigated Corn Production in the U.S. Great Plains to Promote Sustainable Irrigation and Agricultural Best Management Practices

Mary Foltz, Oklahoma State University (R. Koushki, L. Long, J. Warren)

Agricultural management practices improve crop yields to satisfy food demand of the growing population, but also have negative consequences, including production of greenhouse gas (GHG) emissions that contribute to global climate change. Therefore, management practices that contribute most to system GHG emissions should be identified. Accordingly, we estimated the carbon footprint of irrigated corn production under various farmer-selected scenarios in the semi-arid U.S. Great Plains. We considered GHG emissions associated with pre-field (e.g., energy/fertilizer production) and in-field (e.g., groundwater pumping, fertilizer application) activities within fourteen field scenarios in the 2020 Oklahoma Testing Ag Performance Solutions (TAPS) sprinkler corn competition. Direct soil emissions were estimated using the Intergovernmental Panel on Climate Change (IPCC) equation and the Denitrification-Decomposition (DNDC) process-based model. We determined that 63% of the total GHG emission from corn production was associated with in-field activities and that agricultural soil emissions were the overall driving factor. Soil biochemical processes (e.g., denitrification) within agricultural soils contributed an average of 89 g CO_2-eq kg^{-1} corn of the total 271.46 g CO_2-eq kg^{-1} corn estimated from these systems. On-site natural gas combustion for agricultural groundwater pumping and pre-field fertilizer and energy production were the next most influential parameters on total GHG emissions. The carbon footprint was most sensitive to the modeled GHG emissions (i.e., nitrous oxide) from agricultural soil, which had significant uncertainty in the emission factor when using the IPCC model. Further, IPCC predicted emissions were much lower than those estimated by DNDC. Applying the DNDC model enhanced estimations through inclusion of additional agricultural management practices (i.e., irrigation) and weather variability. Overall, this work highlights the need for accurate estimation of field GHG emissions through measurements and model evaluation. Identifying the optimal application rate of irrigation water and fertilizer will help to decrease GHG emissions from groundwater irrigated crops.

Wireless Sensor Networks for Calibrating Numerical Groundwater Models

Nuri Yilmazer, Texas A&M University-Kingsville (T. Saliyu, J. Massa, B. Arowolo, N. Johnson, N. Yilmazer)

In recent years, the declining groundwater levels due to oil exploration in Wintergarden region in South Texas for agriculture is at an alarming level jeopardizing the sustainability of agriculture for now and future. There is an urgent need to develop a real-time monitoring system which provides accurate and reliable information to the decision makers in the community so that they can develop strategies to resolve the issue. In this study, we propose Wireless Sensor Network (WSN) as a real-time data collection and processing technology in the region. The WSN is composed of sensing elements, processing and transceiver units. Each node is equipped with soil moisture sensor, groundwater level and temperature sensors. Each one of these WSN nodes will sense the soil parameters and send this data to the neighboring sensor nodes. The communication between the WSN node is done with data hoping at a Radio Frequency of 900 MHz through the Zigbee protocols. All collected data is relayed to a final sink node in WSN, it is called Gateway node. The Gateway node is connected to a PC where the data collection and data visualization processes will be implemented. The data will be forwarded to a server either an AWS or Google Cloud. The data is shared via a website. We beta-tested this model at Texas A&M University-Kingsville campus, and the implementation functioned successfully. In the future, we will be deployed in the Wintergarden region.

Panel Discussion: Increasing DEI in Western Water Management

Organizer: Ginger Paige, University of Wyoming

Panelists:

Staci Emm, Professor and Extension Educator, University of Nevada (Reno)
Stefan Tangen, Tribal Liaison, North Central Climate Adaptation Science Center
Otakuye Conroy-Ben, Sustainable Engineering & the Environment, Arizona State University
Jackie Tinetti, The Council of State Governments West

Who gets water, how much, and for what beneficial use is being critically examined in many western basins in the face of climate change and growing demands on limited and sometimes decreasing water resources. Western basin states are looking at trade-offs between food security (ag water), energy needs, and maintaining healthy watersheds. Increasing diversity, equity and inclusion in western water resource management is complex and involves legal, cultural, environmental justice, and socio-economic issues coupled with information and knowledge of current and future available water resources. Ideally, all stakeholders are at the table and included in the management and decision making processes.

Panel Discussion: Water in the Archives: A Conversation with Hydrophilic Librarians

Organizer: Patricia Rettig, Colorado State University

Panelists:

Andrew Lippert, University of California, Riverside
Michele Potter, University of California, Riverside
Lisa Crane, The Claremont Colleges Library
Sarah Jones, University of Nevada, Las Vegas

Work on today's water issues often builds on what has been done in the past. Water archives at a handful of universities across the West work daily on saving, organizing, and digitizing important historical documentation that can inform scholars, researchers, and students. The materials are available for use in instruction, research projects, comparative studies, and much more. This panel of archivists and librarians from four different institutions in three different states will engage in a conversation about what they do, the contents of the collections they curate, and how the materials can be useful to a variety of audiences. The panel will also welcome audience questions on the topic. Panelists represent the Water Resources Archive at Colorado State University, Fort Collins; the Water Resources Collections and Archives at the University of California, Riverside; Special Collections and Archives at The Claremont Colleges Library; and Special Collections and Archives at the University of Nevada, Las Vegas. With historical documents concerning various topics in western water law, civil engineering, water quality, irrigation, endangered species and much more, along with documentation on numerous rivers and aquifers, these institutions hold a wealth of material offering numerous research possibilities. Though the participants are all based in the West, conference attendees from anywhere in the country will benefit from knowing more about these collections and will come away with ideas for increasing historical documentation of water resources in their own locales. Attendees will also be curious to know more about drafts of the Colorado River Compact, photographs of the construction of the West's largest dams, oral history recordings with western water leaders, and millions more unique documents.

Communication Research to Minimize Obstructive Water Partisanship and Increase Adoption of Water Research Findings

Sadie Hundemer, University of Florida

Since 2017, the Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) project has been working with stakeholders from agricultural and environmental interests to model alternative land management scenarios to determine the long-term implications for the water sustainability and agricultural success. The findings from this project have the potential to motivate sustainable water policy; however, the likelihood of sustainable water policy adoption depends on broad stakeholder support and the minimization of political polarization. The FACETS Communication Research Team conducted a series of studies to understand existing regional water conflict, predict the manner by which a potential policy could be obstructed by partisan inclinations, and develop strategies to maximize stakeholder and bi-partisan support. This session will describe the communication research and how the findings can increase public use of project findings.

The first half of the session will examine our approach to ongoing water conflict between agricultural and environmental interests. These groups believe that they have very different visions of how water is and should be managed; however, our analyses revealed that much of their perceived conflict is based on misperceptions. By documenting their mental models and allowing each group to “see inside the heads” of the other group, stakeholders were better able to understand why they see things differently and why they have developed misperceptions of one another that impede partnership toward common water goals. The second half of the session details our approach to determining how political partisanship could emerge if water policy is introduced and the effectiveness of preventative communication approaches. Through a combination of assessments and experiments we found that basic regional water facts were prone to partisan rejection; however, with value-oriented messages and messengers, bipartisan support can be achieved.

Factors that Shape Knowledge Co-production in Participatory Modeling

Wendy-Lin Bartels, University of Florida (C. Furman, K. Rowles, M. Masters)

Participatory modeling presents a pathway for generating relevant, credible, and useful science. However, knowledge co-production requires attention to how scientists, community members and other practitioners interact, exchange perspectives, dialog and learn together. This paper offers insight on the "incubator stage" of FACETS, a project in the SE USA, in which stakeholders worked together to develop core modeling components and interpret results. Specifically, we examine factors that shape participants' experience of co-production, the evolution of trust within the group, and the impact of shifting to a virtual exchange space due to the global pandemic.

Indigenous and European Place Names along Streams and Waterways in Delaware (Lenapehocking)
Elizabeth Shields, University of Delaware Water Resources Center

Beginning in Summer 2021, this project was created to initiate important research, conversation, and recognition around the names of waterways and places in our state. There is a rich and long history of the relationships between the Lenape Haki-nk, Susquehannock, Choptank, Nentego/Nanticoke, and Pokomoke peoples and this land we now know as the State of Delaware. We acknowledge both the history and maintained presence of these Indigenous peoples, as well as the existence of their original connections and name associations to the land and water. The goal of this living project is to begin to uncover what available records show and tell of the lineage and possible meanings behind the Indigenous, early European settlers, and commonly known names. Through an analysis of the 1966 United States Geological Survey “Delaware Place Names” Report, a current total of 107 waterways and key land points have been organized, interpreted, and placed, producing a new alternative visual for mapping in Delaware. Next steps of the project will play out in the evolution of the printed sample into a living online map with additional content and context. Given the limitations of the 1966 USGS report, we plan to collaborate with other sources and initiate communication with Indigenous tribal leadership and members around the state for their input on variants, translations, locations, and other vital elements to this process.

Advancing Regional Water Supply Planning to Develop Equitable and Robust Infrastructure Investment and Management Pathways

David Gold, Cornell University (P. Reed)

Globally, urban water utilities are challenged by increasingly severe droughts and growing water demands. In the United States, these challenges are compounded by increasing costs of new supply development and aging infrastructure that strain the budgets of local water utilities. Regional cooperation can help utilities face these challenges by improving the efficiency of existing water sources and exploiting economies of scale to reduce the capital cost of new infrastructure investment. Effective strategies must equitably balance the potentially divergent interests of regional partners, as regional conflict can destabilize partnerships and expose utilities to new risks. The presence of uncertainty in water supply planning problems heightens these risks by masking sources of potential inequity and instability. In this talk, I present new research that advances the development of equitable and robust infrastructure investment and management policies. Using a six-utility water supply partnership in the Research Triangle of North Carolina, I'll first illustrate how multiobjective reinforcement learning aid the development of infrastructure investment and management policies that maintain robust performance across a wide range of future conditions. Next, I'll introduce a new methodology that explores the vulnerability of candidate policies to deep uncertainties (e.g., climate change, demand growth), reveals potential sources of instability within the cooperative partnership, and maps power dynamics between regional actors. Results from the Research Triangle illustrate the potential benefits of regionally cooperative water supply planning but also highlight that regional and individual vulnerabilities are highly interdependent and evolve over time in unexpected ways. These findings emphasize the need to carefully design cooperative agreements that limit the potential for regional conflict. Beyond the Research Triangle, these results are broadly applicable to cooperative infrastructure investment and management problems globally.

Writing the River

Jake Friedman, Colorado State University

The Colorado River system is in crisis. As the reservoir levels at Lake Mead and Lake Powell drop ever closer to deadpool, and the river faces unprecedented drought and aridification due to anthropogenic climate change, it's increasingly clear that the water management policies and practices of the last 100 years are no longer sustainable. Generally speaking, our approach tends to take place within legal or managerial frameworks, addressing the political, economic, and hydrologic issues within the basin. At the same time, we also need to interrogate the deeper ideologies and colonial histories that have enabled this situation in the first place. In this respect, art can play a crucial role in framing the issues within a more critical perspective, emphasizing the human experience, and raising public awareness around the river. (It can also provide a different form of engagement for participants at a conference, breaking up the constant stream of academic panels and presentations.) In this brief talk, I'll share a few of the poems I've been producing around the Colorado River as an MFA student at Colorado State University, ranging from prior appropriation and the Compact to the Lost City under Lake Mead, the Salton Sea, the pulse flow from minute 319, and more. I'll also talk a little bit about my process—how I incorporate language and material from supreme court cases, archeological excavations, and other contemporary and historical documents within the body of the poems. Finally, I'll close with a gesture towards partnership and collaboration, providing some general directions for how water managers, scientists, and other conference attendees can work with artists and writers to address the river.

Making Research in Water Resources More Reproducible: ASCE's Reproducibility Review Program
James Stagge, The Ohio State University

There is strong agreement across scientific fields that replicable workflows are needed for computational modeling and that publishing digital research artifacts (workflow, code, data, output) alongside manuscripts increases the number of people who can access, learn by doing, and ultimately expand upon published research. This talk will highlight efforts by ASCE and the Journal of Water Resources Planning and Management (JWRPM) to implement a new reproducibility peer review system that operates in parallel with typical content reviews for submitted manuscripts. Authors opt in to the voluntary program during submission and share all research materials in a public repository. Reproducibility reviewers then use these materials to independently reproduce all figures, tables, and results, potentially making recommendations to improve the replicability/reproducibility of the submission. The program is voluntary, but offers several incentives in addition to the aforementioned benefits of increased research impact. Currently, papers that meet the reproducibility requirements are published in a special collection with open access fees waived by the journal. Additionally, papers are marked with a bronze or silver reproducibility badge to indicate making some artifacts publicly available (bronze) or replicated (silver). Finally, JWRPM has introduced new annual awards for reproducibility, separately awarding authors and reviewers for their efforts. Several years in, JWRPM has published 6 articles with a reproducibility badge, with 4 more in press, and an additional 17 in review or revision. Based on the success of this program, which began in 2020, ASCE is planning to expand it to journals outside water resources. Want to publish a paper with more impact, learn how to make your results more accessible to our community, or become a reproducibility reviewer? Attend this talk.

Sensitivity Analysis and Parameter Estimation for Holistic Hydrologic Modeling using SWAT+

Salam Abbas, Colorado State University (R. Bailey, M. Almahawis, J. White, J. Arnold, M. White, J. Gao, N. Cerkasova)

Parameter sensitivity analysis is a significant part of effectively identifying key parameters, improving the efficiency of parameter optimization, and quantifying model uncertainty in watershed modeling. In this study, we present a sensitivity analysis approach for the integrated SWAT+ model, augmented to include physically based spatially distributed groundwater modeling with the new *gwflow* module. For our assessment we use a collection of 8-digit watershed models from the National Agroecosystem Model (NAM). The NAM is a field-based, national scale hydrologic model to aid in conservation planning and policy. Main computed groundwater inflows and outflows include pumping, recharge, groundwater-surface water exchange, groundwater-lake exchange, boundary inflow, and transfer to soils. We demonstrate the approach for 5 watersheds located in various regions of the United States to simulate the monthly runoff for 16 years (2000–2015), focusing on areas of tile drainage (Winnebago River), intensive groundwater-surface water interactions (Nanticoke River), groundwater pumping (Cache River), snow-melt dominant (Arkansas Headwaters), and detailed Irrigation and canal seepage (Cache La Poudre). The key parameters of SWAT+ and the *gwflow* module were optimized using the parameter estimation software programs PEST and PEST++. The Nash–Sutcliffe efficiency coefficient (NSE), determination coefficient (R^2), Kling–Gupta efficiency coefficient (KGE), and percentage bias (PBIAS) are used to evaluate streamflow and mean absolute error (MAE) for the evaluation of groundwater level. Two typical sensitivity analyses, namely, the Morris screening, Sobol analysis, are used to determine the critical parameters affecting hydrological processes. Key identified parameters include Recharge delay, aquifer hydraulic conductivity, aquifer specific yield, Streambed hydraulic conductivity, Streambed thickness, curve number, Soil evaporation compensation factor, Plant uptake compensation factor, Percolation coefficient, and available water capacity, Including parameters from the *gwflow* module allows for the identification of all governing parameters in the surface/subsurface system, with results varying significantly if the stand-alone SWAT+ models are used.

Keywords: parameter sensitivity; model calibration; SWAT+; gwflow; Morris; Sobol.

A Web-based Decision Support System for a Better Understanding of Riverine Flood Hazards in the U.S.
Mahshid Ghanbari, Colorado State University (S. Yochum, T. Wible, M. Arabi)

Impacts from riverine flooding are experienced in regions across the United States and globally. In order to build more resilient communities and protect human lives, property, and infrastructure, it is imperative that we expand our understanding of flood hazards and how they vary across ecosystems, river systems, and watersheds. Existing traditional flood frequency analyses could lead to poor communication of flood hazards to decision-makers and the public. An enhanced understanding of these hazards facilitates improved design of infrastructure in and around floodways as well as proper land use management for floodplains and river corridors, among other associated benefits. The Flood Potential Portal (https://floodpotentialbeta.erams.com/), a web-based decision support system, has been developed to assist with this need. The Portal is a map-based tool for illustrating flood variability and predicting flood discharges at user-selected points of interest using a novel flood quantification procedure, the flood potential method. The flood potential method quantifies the central tendencies of record peak discharges at long-term stream gages within zones of similarly experienced floods. The term “expected flood potential” was introduced to represent large flood magnitudes that are generally expected considering the maximum recorded floods in nearby watersheds. At user-selected points of interest, these results are presented alongside of traditional flood frequency analysis results from USGS regional regression and index-flood methodologies. The portal provides practitioners, policymakers, and the public with a “one-stop shop” that informs the quantification of riverine flood discharges for floodplain planning and infrastructure design as well as facilitating an enhanced understanding of how riverine floods vary in space and time.

Initial Results of a Multi-Region, Multi-Year Analysis of Flood Timing, Magnitude, and Severity as Measured Compared to National Water Model Predictions

Iman Maghami, Brigham Young University (D. Ames, E. Perkins, J. Anderson, J. Garcia)

Extreme short-duration rainfall events have been causing catastrophic floods leading to human loss, and property and infrastructure damage in particular in urbanized and densely populated areas. Real-time flood forecasts enable decision makers to take in-time actions to prevent or at least reduce the loss and damage caused by such horrific events. The NOAA National Water Model (NWM), being operational since August 2016, produces real-time continuous hydrologic forecasts for the continental United States (CONUS). A growing body of research has been paying attention to this model. While a few research studies have started exploring the utility of the NWM in flood predictions, to the best of our knowledge, no study has investigated it across multiple regions. The objective of this study, therefore, is to evaluate the utility of the NWM version 1.2 in predicting floods caused by heavy short-duration rainfall events across multiple regions and scales considering different forecast configurations (short-range, medium-range, and long-range) and lead times. Flood forecast assessments are performed by comparing the NWM streamflow forecasts against the U.S. Geological Survey (USGS) observational streamflow. This analysis shows the performance of NWM predictions under different temporal (whether it is best under certain time periods, seasons, lead times, and forecast configurations) and spatial conditions (whether it is best for specific regions or scales). We will present initial results of this study and discuss opportunities to use these results to better interpret and apply NWM forecasts in operational flood management.

Incorporating Flowpaths as an Explicit Measure of River-floodplain Connectivity to Improve Predictions of Floodplain Sediment Deposition

Jonathan Czuba, Virginia Tech (S. Sumaiya, J. Schubert, J. Pizzuto)

Floodplain topographic relief can lead to gradual flooding across a floodplain and increase river-floodplain connectivity. In this work, we show that incorporating hydrologic flowpaths as an explicit measure of river-floodplain connectivity can improve predictions of floodplain sediment deposition. We focus on the floodplain of the South River, Virginia, where historical mercury contamination has occurred and where measurements of mercury accumulation have been used to estimate decadal-scale sedimentation rates. We developed a 2D HEC-RAS hydrodynamic model for the South River downstream of Waynesboro, Virginia, and used simulated model results with sediment deposition data to create predictive multiple linear regression models describing sedimentation across the floodplain. All of our predictive models incorporated a flowpath length from the location on the floodplain downstream to the riverbank as an explicit measure of river-floodplain connectivity that improved our predictions of floodplain sediment deposition (best model with r^2=0.514). We applied our best regression model to our hydrodynamic model results to create a spatial map of floodplain sedimentation rate and discuss differences on three separate sections of floodplain. We found that two sections of floodplain with variable topography had wider, bimodal probability distribution functions (PDFs) of sedimentation rate (aggregated spatially), capturing greater deposition in low-lying areas that were frequently inundated. The third floodplain without this topographic relief had a much narrower log-normal PDF of sedimentation rate with much lower values. Our work highlights how floodplain topography and river-floodplain connectivity affect sedimentation rates and can help inform the development of floodplain sediment budgets.

Hydrologic Responses to Management of Surface Water Resources: A Model Design Study

Justin Bowen, University of Wyoming

The effects of a changing climate and anthropogenic alterations on freshwater resources vary spatially and temporally and need to be understood so that watershed managers can make prudent decisions to improve water resource availability. The complexity, cost, and urgency of managing water resources has increased the popularity of decision support systems (DSS). DSS are powerful tools that merge deep data analysis with powerful prediction capabilities. Several DSS have been implemented to consider the effects of irrigation withdraws and application on hydrologic processes. Although current DSS does not consider the effects of western water law which has induced the vast distribution of water rights through trans-basin diversions. The purpose of this DSS model design study is to investigate the spatial relationships between water rights and water management for agricultural dominated watersheds with the objective of understanding how water rights and their application can inform water resource planning using spatial design and analysis. To accomplish this objective, we integrate spatial water right data into a developed hydrologic-irrigation model that considers water availability and allocation, crop productivity, and the geographic fate of return flows. Preliminary results show water distribution among subwatersheds from trans-basin diversions, estimated conveyance and application efficiencies, potential return flow reuse, and timing of stream regulation and water rights affected. Our study is conducted in collaboration with the Popo Agie and Clear Creek Conservation Districts in Wyoming. Designing a tool that is user-friendly can provide watershed managers the capabilities to investigate and discover practical solutions for watershed improvements. To fulfill this requirement, our tool is displayed in an updatable, intuitive web application. Ongoing work includes developing the DSS to allow end users to run scenarios of efficiency changes and different management approaches during diverse climates.

Understanding the Interacting Effects of Climate and Land Use on Geographically Isolated Wetlands

Frances O'Donnell, Auburn University (C. Barrie, S. Chatterjee, C. Eggert, M. Waters, S. Brantley, S. Golladay)

Geographically isolated wetlands (GIWs) are widespread in many agricultural regions, but their role in mitigating non-point source water pollution is poorly understood and they lack the legal protections of riparian and floodplain wetlands. Our long-term goal is to provide the scientific foundation to establish conservation incentive programs for GIWs. Our study site is southwest Georgia, a karstic region with numerous GIWs and intensive irrigated row crop agriculture. The agricultural GIWs in the study are on working farms and are compared to reference wetlands with forested watersheds. Rain gauges, water level loggers, and sediment traps were installed in each wetland and samples are collected regularly for water quality analysis. We are using these data to model hydrologic and sediment dynamics of the contributing area of each wetland in the Soil Water Assessment Tool (SWAT) with event-based sediment loss modeled with the Modified Universal Soil Loss Equation (MUSLE). We also collected long cores from each wetland, which were analyzed using paleolimnological techniques to quantitatively reconstruct sediment and nutrient dynamics throughout the 50- 100-year period of agricultural expansion. We show through three independent methods (sediment traps, SWAT modeling, and paleolimnology) that long-term sediment storage rates in agricultural wetlands are approximately 1.0 $g/cm^2/yr$. This is much higher than the reference wetlands and similar or higher than sediment storage by other aquatic systems. Paleolimnological analysis also demonstrated that GIWs are storing large amounts of organic carbon (5.5 $mg/cm^2/yr$) and phosphorus (2.9 $mg/cm^2/yr$), though nitrogen storage rates (0.3 $mg/cm^2/yr$) were relatively low. Comparison of the temporal pattern of sediment deposition from the SWAT model with core data indicated that droughts followed by large rain events produced peaks in sediment deposition. It also suggested that SWAT and MUSLE overestimate sediment loss during wet periods. Future work will investigate nitrogen removal in GIWs through measurement of denitrification rates.

Dust in the Wind: Impacts of Water Scarcity on Particulate Matter Concentrations

Alex Maas, University of Idaho (J. Bayham, J. Crooks)

Water scarcity is a major concern in the Southwest, and beyond. As interests compete for water, farmers may elect—or be forced—to leave fields fallow or barren, or otherwise adopt new cropping strategies. Such changes in land use are likely to have competing effects on Particulate Matter (PM) Concentrations, and thus, human health and welfare.

Agriculture contributes to $PM_{2.5}$ and PM_{coarse} concentrations in several ways. First, agriculture is a major source of ammonia (NH_3), which can react in the atmosphere to form fine particles. Field activities (e.g. tilling, harvesting) disturbs fine soils and can lead to substantial wind erosion and dust/PM_{coarse} emissions (Image 1), particularly under arid conditions.

While certain agricultural practices are known to produce PM, land left fallow or barren can also contribute to $PM_{coarse,}$ as dry particles are picked up by wind and other disturbances. In extreme cases, barren land may increase the probability of wildfires, which also contribute to increased levels of PM in the air.

PM emissions from agriculture and PM concentrations in agricultural regions are understudied issues that may be exacerbated by climate change and drought. Policies and decisions designed specifically to address water scarcity, may be suboptimal when the secondary impacts of these policies are included in welfare analysis. In an attempt to preempt poorly designed policy, we investigate the impacts of agricultural land-use, drought, and PM using a novel identification strategy.

A Decade of Saturated Buffer Research: Results from Long-Term Monitoring in Iowa

Gabriel Johnson, Iowa State University (T. Isenhart)

Saturated buffers are an agricultural best management practice designed to remove nitrate-nitrogen from subsurface drainage systems to improve downstream water quality. These practices function by routing a fraction of the nitrate-laden drainage into riparian buffer soils to enhance natural denitrification and plant uptake processes. Implementation and monitoring of these practices began in 2011 in Iowa resulting in more than 40 site-years of data. This study combines published data (2011-2017) with additional monitoring data (2018-2022) to assess long-term nitrate removal performance of these practices across sites and years. Brief methods include monitoring drainage flow with pressure transducers and calibrated weirs, and approximate biweekly grab sampling of drainage and shallow groundwater for nitrate concentration. Total mass load reduction was assessed as the difference in nitrate concentration from streamside wells (i.e., the “outlet” point) and the field drainage (i.e., the inlet point), multiplied by the total treated flow volume. At the time of abstract submission, across 31 site-years, the total nitrogen load reduction averaged 45% (sd: 26%) and ranged from 19 to 81% on average across four sites. Mass load of nitrogen removed normalized for contributing drainage area averaged 4.52 to 14.17 kg/ha across four sites. Additional expected results include full data across 40 site years, nitrate removal performance metrics normalized for saturated buffer length and interannual drainage variability, and assessment of temporal trends in performance. Early results indicate saturated buffers remain highly effective at removing nitrogen but can be limited by high bypass flow.

Analysis of Factors Associated with Dis-Adoption of Irrigation Best Management Practices

Evelyn Osei, University of Arkansas (Q. Huang, K. Kovacs, C. Henry)

The 2018 Irrigation and Water Management Survey reveal that despite only a small decline in gravity irrigated acres from 2013 to 2018 (6.1%), the use of water management practices by producers with gravity systems (e.g., precision leveling, tail-water pits) saw a drop in both the number of farms (23.3%) and acres irrigated (26.2%, USDA-NASS 2018). A better understanding of factors associated with abandonment of IBMPs will have important implications for the relative importance of cost-share programs that promote IBMPs versus measures to slow or reverse the dis-adoption of IBMPs.

The main data set comes from the 2022/2023 Arkansas Irrigated Producers Phone Survey, conducted by the authors, which started in October 2022 and will conclude by February 2023. This study will use IBMPs that are most common and have the largest sample size. A multivariate probit regression will be used to analyze factors that play important roles in producers' decision to dis-continue use of IBMPs. Explanatory variables include a set of dummy variables that equal one if a producer is a landowner, has a bachelor or above degree, the producer is concerned water shortage may occur in the state, whether the farm is located in critical groundwater area designated by Arkansas water policy makers, the degree of risk aversion and the use of social media. A set of continuous variables are also included such as years of farming experience, percent of household income generated from farming, gross irrigated crop sales revenues in 2021, total irrigated acres, percent of irrigated acres that use gravity irrigation, percent of irrigated acres that is rice, percent of irrigation water from groundwater, percent of producers in the county that have participated in any federal, state or local conservation programs in the last five years.

On-Farm Evaluation of Conservation Production Systems for Environmental and Economic Benefits
Dave Spencer, Mississippi State University (J. Krutz, Z. Reynolds, D. Gholson)

Expanding the adoption of conservation practices can reduce agricultural non-point source pollution and aquifer decline in the Lower Mississippi River Basin (LMRB). This research is being conducted to facilitate adoption of scientifically validated conservation practices in the LMRB by demonstrating and evaluating at the field-scale how production systems can be designed to enhance water resources and productivity. Demonstration and evaluation sites were established at six on-farm locations across the Delta region of Mississippi to determine the effects of employing cover crop production systems, soil moisture sensor-based irrigation scheduling, and computerized hole selection on runoff water quality, irrigation water use efficiency, yield, and profitability. Analysis of data from the 2022 growing season is currently underway. The effects of cover crops and irrigation management technologies on erosion, off-site N and P transport, cash crop yield, and field-scale profitability will be presented.

Producer Interviews and Analysis as a Tool for Science Communication in Agriculture

Lacy Barnette, University of South Carolina

It is no secret that water has a huge impact on agriculture and agriculture on water. There is an array of research addressing water efficiency and best management practices, but a key component of that research and eventual implementation in the field involves science communication. Interviews are one way to build relationships as well as better understand decision making, motivating factors, and potential barriers for in-field implementation of researched practices. Two cases that utilized producer interviews will be presented to compare the outcomes of two different interview structures. Interviews were conducted with South Dakota producers – farmers and ranchers – that have implemented climate-smart, regenerative agriculture practices into their operations. In Case A with open-ended, unstructured interviews, fewer of the specific implemented management practices were detailed but instead more motivating factors like family were highlighted. In Case B, semi-structured interviews were utilized which gave rise to more insights into key management practices and outcomes but less on producer motivation. All interviews in both cases discussed water including water infrastructure, water quality, and drought resiliency. Both interview sets can be useful tools in informing how research is communicated and can provide important context for improved chances of implementation. Even though both interview styles provided insights and supported stakeholder engagement, it is crucial that researchers have clear goals for their interviews to determine which style is more appropriate based on those goals. The purpose of sharing these cases is to display the outcomes from two different interview structures to help researchers and practitioners determine which might be a better fit to implement based on their time, project scope, and desired information. Additionally, these cases are shared to encourage others to view interviews as a possible tool to engage stakeholders, guide science communication, and increase chances of research implementation.

Panel Discussion: Adapting Agriculture to a Drier Future from the Great Plains to the Central Valley
Organizer: Noah Silber-Coats, New Mexico State University

Panelists:

Emile Elias, USDA Southwest Climate Hub
Sam Fernald, NM WRRI
Jamie McEvoy, Montana State University
Amy Kremen, Colorado State University

Building on a series of paper sessions presenting recent research on the impacts of dwindling water resources on agriculture across the western U.S. and ways to manage this reality, this panel convenes experts from around the region to discuss the following questions: How have reduced water supplies and drought impacted producers in the areas where the panelists work? Which tools or strategies - whether technological or institutional - have shown positive results in terms of building resilience to a hotter, drier future for agriculture in the western U.S.? What are the barriers to implementing these solutions more widely? What opportunities exist to collaborate between the many ongoing research and outreach efforts related to water scarcity across the region? Participants are involved in research and outreach programs covering a variety of topics and locations, from managed aquifer recharge and desalination in groundwater-dependent irrigated agricultural systems in California's Central Valley to training irrigators on advanced water management techniques in the Great Plains.

Temporal Configuration - Unlocking Hidden Streamflow Properties

Participatory Session led by Richard Koehler, CEO Visual Data Analytics, LLC

Analytical tools are needed to identify and quantify artificial short- and long- term discharge fluctuations, which can disrupt the natural processes of a river. To measure the properties of discharge magnitude, frequency, duration, timing and flow change, existing tools typically use a subset of metrics selected from over 170 descriptive statistical indices. The metrics are usually based on multi-day mean or median discharges with associated variance or use a single value to describe the entire dataset. However, these source indices do not quantify the temporal configuration of streamflow, an additional hydrologic property that is often overlooked.

To address this situation, a non-index approach to quantify all streamflow properties has now been developed using analysis methods based on the lag (1) temporal autocorrelation signature of the streamflow. The discharge (Q), discharge change (dQ/dt), and rate of discharge change (d^2Q/dt^2), along with sequential summations, are presented in novel infographics. A dam release river impact case study for the Colorado River at Lees Ferry, Arizona, is included to demonstrate this innovative way of analyzing streamflow datasets. The result is a set of new tools which yield detailed information about the hydrologic regime, are highly customizable, and can either be used as a stand-alone analysis or be integrated into other existing data analysis techniques. The end result is a better understanding of the hydrologic regime, more focused research, and more effective management planning.

Lessons Learned on Increasing DEI in Water-Related Fields
Participatory session led by Karen Schlatter, Colorado Water Center

Diversity, equity, and inclusion (DEI) initiatives have increased significantly in the past several years, including those that focus on increasing recruitment, retainment, and career pathways for historically underrepresented students and professionals in water-related fields. So, how is that all working out? What are the impacts of such initiatives in the water sector? What are the experiences and perspectives of students, academics, and professionals participating in such initiatives? We propose a roundtable session focused on discussing experiences and lessons learned to gain insights on how to improve DEI-related programs and projects in water-related fields. Colorado Water Center Student Fellows from underrepresented groups will drive the session, including helping to define roundtable prompts and organizing the session.

Roundtable prompts for discussion include:

1) Increasing DEI is a large goal with many subsets and challenges to overcome. What are some lessons learned on how to increase DEI in a manageable way?
2) What is working? What some examples of DEI and water related programs/actions that have been beneficial and why?
3) How has DEI changed the collaborative space of water-related fields?
4) What are the major gaps with DEI and water? How do we close the gaps?

The session will focus on fostering meaningful discussion between undergraduate and graduate students, academics, and professionals. Each roundtable will have a facilitator and note taker to encourage positive and productive discussion and make note of key points. Each table will discuss one prompt, and groups will rotate tables until everyone has discussed all of the prompts. A plenary discussion at the end of the session will highlight key points and themes that emerge out of the roundtable.

Assessing Hydrologic Fluxes in the Upper Colorado River Basin using the SWAT+ Model

Muhammad Raffae, Colorado State University (R. Bailey, J. Arnold, M. White)

The Colorado River serves as the primary source of water for over 40 million people and supports several sectors of the economy in the American West. However, the region is currently experiencing a multi-decadal drought, with major reservoirs approaching dead-pool levels. Therefore, understanding the overall hydrology and spatiotemporal patterns in the river basin is critical for addressing water management issues and improving water management practices, including sustainable groundwater abstraction. In this study, surface and subsurface flows and hydrological fluxes, including streamflow, groundwater flow and storage, groundwater pumping, groundwater-surface water interactions, floodplain interactions, tile-drain flow, and canal seepage, were simulated for 60 8-digit watersheds in the Upper Colorado River Basin (UCRB) using the Soil and Water Assessment Tool Plus (SWAT+) model, augmented with the *gwflow* module to simulate physically based spatially distributed groundwater modeling. Each cultivated field in the UCRB is included as an individual hydrologic response unit, with irrigation source (stream, aquifer, reservoir) specified for each. Each 8-digit watershed model is calibrated and tested against available historical records of streamflow and groundwater head. Preliminary results show that groundwater discharge to streams and vice versa, saturation excess flow, and groundwater pumping are predominant fluxes in most of the watersheds. The findings of the study will be applied to address water supply and management issues, such as water distribution between different water-using sectors, water diversions, groundwater abstraction and recharge, environmental flows, and impacts of climate change on water resources. In the long run, the findings can be used to shape water policy to achieve regional integrated water management.

Evaluating Historic and Future Changes of Soil Temperature, Vegetation Distribution, and Permafrost Degradation in the Arctic

Aleksey Sheshukov, Kansas State University (W. Zhou, M. Zhu, T. Zhang, V. Ivanov, J. Wang, D. Liu)

The Arctic has been warming at an accelerating rate over the last several decades causing the expansion of tall trees and shrubs into tundra across polar regions, so called a 'greening of the Arctic' effect. This encroachment of tall vegetation has potential to modify the dynamics of energy and mass partitioning at local and regional scale and have immediate impact on hydrological fluxes with feedbacks to the climate system and permafrost degradation. This study aimed to develop mechanistic and quantitative understanding of such implications with micrometeorological field observations, historical data analysis, and novel process-based modeling in the western Siberia. Historic imagery series uncovered spatiotemporal patterns of the encroaching tall vegetation related to microtopography and snow cover with the preference for tree growth at the surfaces with overland flow divergence characteristics. The developed framework of integrating semi-analytical and numerical soil heat transfer models with the state-of-art uncertainty quantification machinery was able to reconstruct ground heat fluxes using field measurements, outputs of the Global Climate Models, and shallow soil temperatures from borehole measurements. The long-term projections of soil temperature change in the studied permafrost region showed higher degree of warming than the global surface average from the available future climate models and scenarios. This has direct implications on the permafrost degradation and affected ecosystems, infrastructure, and indigenous communities.

Seeking Best Management Practices for Salinization Mitigation in Irrigated Agricultural Regions Using an Integrated Hydro-Salinity Model

Soheil Nozari, Colorado State University (R. Bailey, M. Rouhi Rad, J. Suter, D. Sahoo)

Irrigation-induced salinity has become a major water quality issue that plagues irrigated crop production as well as aquatic environments across the globe. This problem is often prevalent along alluvial river valleys in semi-arid and arid areas where intensive irrigation induces excessive dissolution of already deposited salt minerals in the soil vadose zone, leading to increased salt loading and recharge to the groundwater stored in the underlying shallow alluvial aquifer. In addition to increased salt loading to the streams, the elevated saline groundwater level leads to the accumulation of salts in the soil root zone through evapoconcentration, resulting in crop yield reduction. This anthropogenic phenomenon creates a vicious cycle affecting both crop producers and the environment; the producers tend to maintain irrigation at current high levels to leach out the deposited salt from the root zone, while intensive irrigation consequently results in increased salinity levels in the root zone as well as water bodies. To address such a complex situation, a variety of management practices should be sought that reduce salinity levels both in the root zone and water resources. While several studies have attempted to assess different salt management practices using hydro-salinity models, none have conducted a comprehensive assessment using a model capable of simulating the movement and fate of salt ion species in all major components of an irrigated watershed system. In this study, we employ SWAT-MODFLOW-Salt, a recently developed integrated hydro-salinity model, to compare the effectiveness of different salt management practices across the Lower Arkansas River Valley (LARV) in southeast Colorado. The hydro-salinity model used in this study enables us to explore the impacts of a variety of management practices such as horizontal subsurface drainage, fallowing, and switching to more salt-tolerant crops on salinity levels in the root zone, groundwater, and streams.

Keywords: Hydro-salinity model, Salinity, Irrigation, Lower Arkansas River Valley, Salt management

Uncertainty Quantification of Salinity Transport Simulation for Integrated Hydrological Models

Seonggyu Park, Blackland Research & Extension Center, Texas A&M AgriLife, Temple, Texas, U.S.A. (X. Zaichen, T. Abitew, J. Jeong, R. Bailey, C. Green)

A recent version of the Agricultural Policy / Environmental eXtender (APEX) model integrates the physically-based, spatially distributed groundwater flow model MODFLOW, reactive transport model RT3D, and a new salinity module. The APEX-MODFLOW-RT3D-Salt (AMRS) model now simulates the fate and reactive transport of eight significant ions (SO_4^{2-}, Cl^-, CO_3^{2-}, HCO_3^-, Ca^{2+}, Na^+, Mg^{2+}, K^+) in soils, aquifers, and stream, exploring the hydrological dynamics and solute transports in a complex watershed system. However, the integrated modeling process adds up the number of parameters and inputs from each model, increasing uncertainty during model prediction. In this study, we used PESTPP-iES that reformulates Gauss-Levenberg-Marquardt (GLM) algorithm with the iterative Ensemble Smoother (iES) to alleviate the computational burdens due to the high dimensional parameter spaces. A script-based workflow, a Python package called apexmf, is developed for the use of PESTPP-iES with the interactive Jupyter notebooks and for increasing the credibility of the AMRS model as a decision tool while maintaining the workflow transparent and reproducible. We present the workflow and performance of the uncertainty quantification (UQ) and parameter estimation (PE) analysis in a case study of the AMRS application in the Upper Green River watershed of the Colorado River basin, USA. The case study has more than 100 significant parameters, such as initial salt ion concentration and fraction, soil moisture retention parameter, Hargreave's PET coefficient, hydraulic conductivity, specific yield, riverbed conductance, riverbed thickness, assigned as field and boundary parameters. A high-dimensional PE was performed to reduce uncertainty by comparing monthly average simulated and observed salt ion concentrations in streams and daily concentrations in the aquifer.

Hydro-Economic Modeling System for Understanding the Dynamics in the Food, Energy, and Water Nexus in California

Enrique Triana, RTI International (J. Baker, F. Moreda, G. Van Houtven)

California will continue to experience changes in water resource consumption patterns driven by renewable energy sources goals, water scarcity, climate change, aquifer sustainability goals, land resource scarcity, and other economic factors. Our overarching research goal is to understand the current interrelationships and dynamics in the nexus of food-energy and water to analyze potential future outcomes and inform policies that help and support transitions to achieve multi-faceted sustainability and climate-oriented policy goals. In this presentation, we discuss a system built to simulate the water allocation in a large region of California using economic factors based on the opportunity cost of water, leveraging existing modeling approaches and publicly available datasets. The main objective of the new modeling system is to simulate the dynamics of changes in agricultural land use at the extensive and intensive margins when driven by combination of renewable energy expansion in the region (in particular solar energy farming), as well as new irrigation constraints imposed by the Sustainable Groundwater Management Act (SGMA). The analysis is based on a set of conditions that could incentivize changes, including (1) water stress where groundwater sustainability restricts groundwater use and environmental flows goals and water availability restricts surface water diversions, (2) the demand for solar energy is expected to make feasible and economically attractive to switch agricultural productive land to solar farming. While there is an economic driver for the land change, available water will be differently distributed based on the spatial re-distribution of resource demands following agricultural land use changes, so it is key to understand and analyze the whole system response of these potential policy-induced changes. In addition, the new modeling system will allow altering the water available in the system to be distributed to simulate different future hydrologic conditions under climate change.

Economic Value of New Jersey Tributaries to the Delaware River

Lydia Franks, University of Delaware Water Resources Center (E. Shields)

The New Jersey tributary watersheds of the Delaware River encompass 908 square miles across five counties in the northwest region of the state (Mercer, Hunterdon, Morris, Warren, and Sussex) and are located within the Piedmont, Highlands, and Valley and Ridge physiographic provinces. In recognition of the immense intrinsic value of these watersheds, the economic value was analyzed to demonstrate their significance in providing major economic benefits to the regional economy. For this study, economic value was examined as: economic value directly related to the New Jersey tributary water resources and habitat, value of goods and services provided by the New Jersey watershed ecosystems, and employment related to the New Jersey watersheds resources and habitat. Published literature along with field data collected directly from participants using and enjoying the resources in the New Jersey watersheds were referenced to derive economic estimates. To generate meaningful comparisons, these values were converted to 2020 dollars based on the mean annual change in the Northeast Region Consumer Price Index.

Improved water quality, water supply, fish and wildlife, recreation, agriculture, forests, and public parks all support the region's economy, with public parks, forests, and recreation accounting for more than half of its annual economic value. The findings of this study are exemplary in converting the true value of our watersheds and relative resources, setting a precedent for how we can communicate their worth.

Policies to Achieve Sustainability in the Colorado River Basin under Climate Change Conditions and Growing Demand: A Hydro-economic Analysis

Daniel Crespo, University of California, Riverside (M. Nemati, A. Dinar, Z. Frankel, N. Halberg)

Colorado River Basin faces a supply crisis that makes the water system vulnerable to failure, economic losses, conflicts between regions and water users, and ecosystem degradation. The crisis results from water management that allows excessive water withdrawals, legal restrictions established on historical facts, and decreased water availability due to climate change. The agricultural sector, urban centers, hydropower production, and aquatic ecosystems compete for the exhaust water resources in the basin. The shrinking water availability and growing demand for water will exacerbate existing problems, hampering water management. This article evaluates several alternatives to water management to identify the sectoral and spatial trade-offs of water use by the agricultural sector, urban centers, hydropower production, and aquatic ecosystems. A hydro-economic model is developed to assess current and alternative water allocation's economic impact on drought, climate change, and growing population. The model examines coalition arrangements among some or all basin states, Tribal Nations and Mexico and the implementation of institutional reforms such as water markets, proportional sharing, and mechanisms that promote water savings. The development of existing but unused Tribal Nation rights is analyzed to evaluate its impact and to determine the potential for new agreements. Simulation shows that shrinking water allocation promotes efficiency improvements and strengthens the sustainability of the water system. However, droughts and climate change erode the benefits of water use and environmental conditions. Urban centers endure heavy welfare reductions due to water use restrictions, but purchasing water from irrigation districts alleviates the burden and enhances the social surplus. Water exchange and side payments (for improved water savings) between states and irrigation districts indicate potential improvements in water use efficiency. Maintaining tribal Nations' rights and establishing environmental flows rectify the inefficient use of water by other users.

Water Market Design Features and Transaction Costs: A Comparative Analysis of Two Snowfed River Basins in the Arid Western United States

Loretta Singletary, University of Nevada Reno (E. Koebele, J. Rego, K. Wright, A. York)

In snowfed rivers in the arid western United States, irrigated agriculture accounts for most freshwater withdrawals, water rights are fully or over-allocated, and water demand is increasingly diverse and water supply more variable. Trading pre-existing water rights has become key to obtaining additional water. As a result, various water market arrangements have emerged that aim to redistribute increasingly scarce water resources from agricultural to urban and environmental uses. Understanding how market features impact the costs of participation is critical for designing attractive market programs that promote sustainable water use. We investigate the design and associated transaction costs of water markets that have been implemented in the Walker River Basin in northwestern Nevada and the South Platte River Basin in northeastern Colorado. In the Walker River Basin, both permanent transfers of agricultural water rights and temporary leasing of agricultural storage waters are redistributing water to environmental instream flows to restore the basin's desert terminus lake. In contrast, while most historical transfers in the South Platte Basin have been permanent, recent collaborative water sharing arrangements allow agricultural water users to temporarily lease water to municipal uses in Colorado's rapidly urbanizing Front Range while retaining their water rights. Through semi-structured interviews with stakeholders representing competing water uses in each basin, we assess how the transaction costs associated with various market designs relate to economic, social, institutional, and infrastructural aspects of moving water. Results suggest that temporary water transfers may have comparative economic and infrastructural costs to permanent transfers but may be more desirable due to their lower long-term social and institutional costs, though this varies depending on the use to which the water is being traded. Our findings lend insight into ways to improve market design, encourage participation, and promote water sustainability under changing water supply and demand dynamics.

The Effect of Cropland on Drinking Water Treatment Costs: A Cost Function Analysis of Municipal Groundwater Systems in Wisconsin

James Price, University of Wisconsin-Milwaukee (M. Heberling, D. Ebert)

Safeguarding source waters from contamination is often considered an essential component of drinking water provision. Whether these efforts are cost-effective relative to in-plant treatment options requires an understanding of hydrological, chemical, and biological processes, as well as knowledge of how treatment costs are affected by changes in source water quality. Quantitative evidence on the latter relationship is limited. This study estimates cost functions for municipal groundwater systems in Wisconsin, which relate treatment cost to production volume, factor input prices, and source water quality, where relative cropland coverage in the proximity of wellheads was used as a surrogate for water quality. This study estimates cost functions with both variable treatment cost and total treatment cost. Variable costs refer to expenditures on labor, electricity, and chemical inputs, while total costs further include expenditures on capital equipment. Results suggest that a 1% decrease in cropland relative to other land types is associated with a 0.07 – 0.09% decrease in variable treatment costs. A 1% decrease in cropland is associated with a 0.1 – 0.13% decrease in total treatment costs. Given the limited number of groundwater system studies, the results fill an important gap in the literature and offer insight into the potential avoided-cost benefits of wellhead protection.

Efficiency and Equity of Posted Price Markets for Irrigation Water

Dawoon Jeong, Purdue University (J. Sesmero, C. Reeling)

Motivated by key features of agricultural water markets, we study the efficiency of posted-price markets where water is thinly traded among heterogeneous farmers. Thin markets are a prominent market feature in existing water markets. Yet, much remains unexamined regarding the equilibrium in such markets, and how market designs affect market performance (efficiency and equity). We examine one feature of market design: market recursiveness. In recursive markets, trade is allowed multiple times over the growing season, while in non-recursive markets trade opportunities are limited. Recursive designs are similar to Australian water markets, and non-recursive designs are like the U.S. markets as trades are more limited. We theoretically find that recursive trading lessens efficiency and harms buyers substantially (thus lessens equity), when farmers are highly heterogeneous in contrast to the conventional wisdom – more trades are better in clearing markets. It does so by weakening competition among water sellers when anticipating recursive trades in the future, triggering inefficiency and inequitable distribution. In the lab experiment, however, we show such counterintuitive effects of recursive market design on efficiency are trivial due to human subjects' out-of-equilibrium behavior. That is, human subjects find non-recursive markets are too complex to coordinate between sellers and buyers, failing to maximize gains from trading (i.e., efficiency). Thus, contrasting to our theoretical model, we confirm the conventional wisdom- i.e., allowing recursive trading increases efficiency. We also observe out-of-equilibrium behaviors by sellers under recursive markets; that is, sellers behave less competitively than predicted under non-recursive markets whereas they are more competitive than predicted under recursive trading. Thus, as opposed to the theory, we find that recursive design does not induce inequitable distribution. To sum up, no trade-off between efficiency and equity is expected when farmers' water valuations are highly heterogeneous. However, when farmers are relatively homogenous, we find evidence of such trade-offs.

Aquatic Invasive Species Prevention: Getting the Best Bang for the Buck!

Nichole Angell, University of Minnesota (T. Campbell, A. Bajzc, V. Brady, A. Doll, A. Kinsley, J. Dumke, R. Keller, N. Phelps)

Aquatic invasive species (AIS) are a growing threat to water resources resulting in re-engineered ecosystems and expensive management actions. Boater education, watercraft inspection, and hot water decontamination are popular prevention strategies for AIS that spread through the recreational boating pathway; however, few studies have quantified the effectiveness of these approaches. In this study we estimated the effectiveness and costs of AIS prevention practices performed by boaters, watercraft inspectors, and hot water decontaminators. To estimate effectiveness, participants (n=144) recruited at public water access sites in Minnesota and Wisconsin and were asked to inspect and remove AIS from a boat that had been realistically staged with macrophytes, zebra mussels, and spiny water flea. The types of organisms and the amounts of AIS removed were used to estimate effectiveness for each prevention method. Additionally, interviews with MN county AIS managers were conducted to gather itemized spending information on the three preventions in question. Our results suggest that watercraft inspection is a cost-effective method of prevention for most boats and hot water decontamination is an important tool for high-risk boats, however decontamination protocols are difficult to effectively execute and the economy of scale for these preventions must be considered with long term management plans. Furthermore, boater education helps reduce risk when inspectors cannot be present at public water access sites due to limited funding and staffing. Ultimately, these data will be incorporated into the online decision support tool, AIS Explorer (www.aisexplorer.umn.edu) to guide future management decisions.

NWIR center and other institutes supporting the work: Water Resources Center (WRC) at the University of Minnesota (UMN); United States Geological Survey (USGS); Minnesota Aquatic Invasive Species Research Center (MAISRC)

Evaluation of a Potentiometric Soil Nitrate Sensor for Detecting Nitrate Transport in Glass Beads

Cassandra Bonfil, University of California Davis (F. Ogunmokun, P. Goodrich, C.L. Baumbauer, L. Lahann, S. Koh, A.C. Arias, I. Kisekka)

Nitrate (NO_3) serves as the main nitrogen source for plants and is crucial for protein synthesis. However, in irrigated cropping systems, the solubility of nitrate increases the risk of leaching into groundwater, raising concerns for human and environmental health on a global scale. Monitoring soil nitrate traditionally involves laborious, time-consuming, and expensive methods. To address this concern, new developments in sensing technologies have been emerging. This study evaluated the performance of an experimental printed potentiometric nitrate sensor to two commercially available nitrate sensors: a combined nitrate selective electrode (Xylem Analytics™) and an optical nitrate sensor (Badger Meter Inc.). The study was conducted in a laboratory setting using soil columns (35 cm high, and 15 cm ID) packed with glass beads at a bulk density of 1.56 g/cm^3 with three replications. A single potentiometric nitrate sensor was installed in the center of each column, while the commercial sensors were placed in external flow-through cells. To start the experiment, the columns were saturated with deionized water from the bottom, at a flow rate of 1.5 mL/min. Once fully saturated, a nitrate solution (50 mg/L NO_3-N) was pumped into the columns at a flow rate of 20 mL/min. High throughput nitrate concentration was continuously measured per minute by the three sensors for NO_3-N breakthrough. Initial findings show that the experimental potentiometric nitrate sensor could be used to measure nitrate levels in the soil. However, this research is in its early stage, proof-of-concept results will be presented and discussed.

Complex Network Analysis of Temperature across the United States

Kehinde Bosikun, Kansas State University (T. Jamali, B. Ghanbarian)

The implications of climate change on people, the environment, and ecological systems are extensive, necessitating multidisciplinary collaborations to develop effective and novel solutions. Understanding the Earth's climate system is the first step in investigating climate change. The climate system comprises numerous nonlinear sub-systems with mutual nonlinear interactions and feedback loops active on a wide range of temporal and spatial scales. Complex network theory has proved itself an effective method for studying such complex and interconnected systems. Therefore, analyzing the climate system based on complex networks can provide critical insights into the underlying dynamics of the evolving climate system. During the last decade, complex network theory has been intensively applied to studying climate, where climate networks are a typical representation. In this study, we aim to investigate spatiotemporal temperature patterns and extreme events across the Contiguous United States (CONUS). For this purpose, we apply complex network theory in combination with other methods, such as edit distance. First, we construct the temperature network by determining the similarity matrix based on the time warp edit distance (TWED) method. The TWED measures the minimum cost of edit operations needed to transform one discrete time series into another. The adjacency matrix is then determined by finding the statistically significant links. Next, we calculate the network characteristics using network measures such as degree centrality and clustering coefficient and interpret the results in terms of atmospheric processes to reveal important dynamics in the climate system.

Improving Water Use Data and Understanding of Rural Water Suppliers

Kaylie Carver, North Dakota State University (C. Hargiss, J. Norland)

Little is known about municipal, industrial, and rural water use in much of the United States beyond a yearly total reported to a water agency, or billing held at the municipal level but not aggregated. In recent years the USGS has attempted to increase information at the state and national level through the Water Use Data and Research efforts. Recent research in North Dakota has sought to determine per capita coefficients for municipal and industrial categories across different size cities, as well as investigate the impact of oil development on municipal and industrial water in the Bakken region. During this research, it was revealed there is a lack of information on rural water use. As more water goes to a single water use distributor, it makes it harder for governing bodies to assess use, per capita coefficients, and plan for future water needs. The goal of this project was to assess rural water use, the organizations governing its distribution, and how rural water use impacts the larger story of water use in an area. A survey was conducted of all rural water managers across the state of North Dakota to assess sources of water, how it is being used, and analyze rural water using a social network analysis. Survey results indicate a loosely centralized social network among North Dakota rural water districts, with most districts interacting with a few major network actors. The collected water data highlights the range of customers of rural water districts and indicates some seasonal variation in use. Information from this study can be used by water managers across the United States to better understand water use and aid in water projections.

Soil Water Dynamics In Semi-Arid Cotton Conservation Systems

Christopher Cobos, Texas A&M AgriLife Research (K. Lewis, J. Burke, W. Keeling)

Water availability and sustainability are essential to the continued agricultural production of the U.S. Great Plains. The Southern High Plains (SHP), located in the semi-arid southern portion of the Great Plains, produces approximately 30% of the U.S. annual cotton production. The continued unsustainable withdrawal of the Ogallala Aquifer for irrigation, paired with the potential increase in annual mean temperature due to climate change puts the future agricultural viability of the region at risk. Our objective was to quantify the amount of water saved using conservation tillage and cover crops in semi-arid cotton production systems compared to conventional continuous cotton systems (CT). The research purpose was to increase producer adoption of conservation systems (no-till continuous cotton with a single species cover crop, R-NT; and no-till continuous cotton with a mixed-species cover crop, M-NT) by reducing irrigation inputs to increase both water and economic sustainability on a regional scale.

Reducing Water Conflict through Student Led Rancher Funded Irrigation Administration in the Brush Creek System

Joseph Cook, University of Wyoming (K. Bracken, A. Jackson, S. Miller)

The Brush Creek/French Creek irrigation system (approximately 24000 irrigated acres) is in southeast Wyoming on the western slopes of the Snowy Range. This ranching community had gone through a half century of tumultuous irrigation fights stemming from a complex system of water right exchanges and return flow dependent subdrainage rights. In the wake of the 2012 drought, the ranching community banded together over a common goal to resolve their differences to ensure a more stable water supply future. The University of Wyoming in partnership with these ranchers, the governor's office, and the State Engineer's office developed a collaborative management strategy to resolve on the ground disputes and ensure equitable and impartial day to day management of the irrigation system. Aided by increased gauging capacity, system understanding, and a standardized approach to calculating near-real time water rights allocation, the system has undergone a significant drop in interrancher conflict with improved collaboration, water efficiency, and transparency. The University provides day to day administration of the system with a supervisor, an administrator and a Ditchrider. These roles take on three main tasks: conflict resolution, water allocation and dispersal, and day to day maintenance and prevention. This provides a unique opportunity for students to manage a complex irrigation system and develop conflict resolution skills setting them up for careers in water management. The project is entirely rancher funded with administration costs coming out to approximately $2/acre.

Influence of Organic Amendments on Nitrogen Dynamics under Agricultural Managed Aquifer Recharge (Ag-MAR)

Wenyi Cui, UC Davis (H. Dahlke)

Agricultural managed aquifer recharge (Ag-MAR) is a practice to sustain groundwater reserves by recharging excess surface water such as flood flows into aquifers during the winter rainy season. Uncertainty remains on the long-term effects of Ag-MAR on leaching of legacy nitrogen from farmland to groundwater. Previous studies focused on increasing denitrification potential during the flooding period. However, when flooding has ended and soils drain, the re-entry of oxygen into the soil stimulates mineralization of organic-N thereby increasing soil NO^{3-}, which could be a valuable nutrient source to crops in the following growing season, possibly reducing fertilizer inputs. This research aims to model the influence of organic amendments (e.g. crop residue, compost) on carbon and organic N pools, denitrification during recharge, and the mineralization after recharge. The study site is located in the Central Valley, California, where a fallow field was flooded in the winter for 8 days continuously for groundwater recharge. The field was then planted with processing tomato the following growing season. DSSAT, the Decision Support System for Agrotechnology Transfer, is a suite of integrated, process-based models that simulate crop growth and development. This research applies DSSAT to simulate soil organic matter, soil nitrogen, and crop response under different management scenarios. Initial findings indicate that organic amendments from the last growing season can promote denitrification during flooding period when the soil is under anaerobic conditions. Further, organic amendments can also promote mineralization after recharge events and supply growing season N demand. Besides, simulation results suggest that Ag-MAR increases soil water storage and provides moisture needed for crop growth.

Spatial Differentiation of Stream Geochemistry in a Subwatershed Affected by Coal Mining in Appalachia

Flor Guerrero, West Virginia State University (O. Awoyemi, A. Kemajou, A. Hass, M. Gonzalez, F. Rojano, D. Huber)

West Virginia is a headwaters state that contributes substantially to the Ohio River watershed. WV also lies within the Appalachian Coalfield Region with extensive mountaintop mining. Coal mining influences water resources by changing hydrogeological conditions. The chemical and/or microbial weathering of metal sulfide-rich rocks produces sulfuric acid, which leads to the formation of AMD. AMD typically has low pH and elevated concentrations of sulfate and metals, however, AMD impacted streams may have a neutral pH and still be severely damaged. Our objectives were to compare water and sediment chemistry against microbial diversity in a headwaters stream damaged by surface mining, but with a circumneutral pH. Sediment and water samples were collected from seven locations near an AMD seep and surface mining. The upper sediment layer was sampled (1-10 cm). Chemical analysis was done on replicate sediment and water samples, and microbial DNA was extracted from sediment. Illumina sequencing and Earth Microbiome Project protocols were used for 16S rRNA gene diversity. Chemical analysis was done with ICP-OES and Dionex Ion Chromatography. About 1 million 16S rRNA sequences were analyzed using QIIME-2. Statistical analysis (PCA, CCA, Discriminant Analysis, Pearson correlation, and hierarchical clustering) were done using R (v. 4.1.2). Both Discriminant Analysis and PCA showed increased spatial differentiation for water samples compared to sediment. Iron and sulfate occurred in opposite gradients in the water while, in the sediment, both decreased downstream. The most abundant species are related to the biogeochemical cycles of iron, sulfur and nitrogen, and belong to the families of *Comamonadaceae, Vicinamibacteraceae, Nitrosomonadaceae, Rhodobacteraceae,* and *Gallionellaceae*. The species varied depending on the sediment/water chemistry at each location. In conclusion, the spatial differentiation of geochemistry occurred more rapidly in water than sediment. Funding by USDA-NIFA-2019-38821-29065.

Quantifying Sediment and Phosphorus Loss from Streambank Erosion in Two Illinois Agricultural Watersheds

Justin Higa, Southern Illinois University Carbondale, School of Forestry and Horticulture (J. Schoonover, K. Williard, J. Gillespie)

While phosphorus and sediment pollution from agricultural sources are well documented, there have been few studies quantifying streambank erosion impacts on sediment and phosphorus pollution in Illinois. Two streams were selected for this study: Lost Creek and East Fork Shoal Creek, two tributaries that flow into the Kaskaskia River. The main objective of this study is to quantify streambank erosion along these two streams and to identify what proportion of total sediment and phosphorus pollution yield can be estimated to be sourced from erosion. Bank erosion will be quantified using erosion pins and topographic surveying methods. Erosion pins will be implemented at three banks along each stream, while topographic surveys will be conducted annually at ten cross-sections along each stream. Additionally, unmanned aerial vehicle imagery will be utilized for agricultural field sites to check topographic data and visually observe stream channel movement. Bank phosphorus storage will be calculated using soil nutrient analyses and soil bulk density samples. Soil samples will be collected at three heights on the bank to identify any differences in nutrient content and compaction across the entire bank. Soil sample results and quantified bank erosion will be analyzed to form an estimated loss of sediment and phosphorus from streambank sources. These values will be compared to annual sediment and phosphorus yield calculations from ISWS to determine a proportion of total pollution that can be sourced to erosion impacts.

Flood Risk in Redlined Communities

Gabe Lara, Pennsylvania State University

Climate change is increasing the frequency, length, and severity of urban flooding. High-frequency events such as nuisance flooding due to sea-level rise and catastrophic natural hazard events (e.g., storm surge from a tropical or extratropical cyclone) are worsening economic loss and death in urban communities. Recent climate catastrophes have emphasized flooding's disproportionate impact in urban areas. For example, flooding from Hurricane Harvey and Hurricane Katrina disproportionately impacted African American areas, with such communities suffering the most severe flood damage. (Hong et al., 2021; Howell and Elliott, 2018, 2019; News, n.d.) Urban flooding affects a diverse spectrum of household demographics, although the most vulnerable populations, mostly constituted of low-income, minority households, are disproportionately impacted.

This study addresses this issue by examining the relationship between Hurricane Sandy flooding damage and the historical Home Owner's Loan Corporation (HOLC) housing appraisal policy (i.e., redlining). I find that redlined homes are estimated to experience greater flooding and likelihood of inundation than non-redlined homes.

These results support previous findings linking redlining and environmental hazards. Additionally, I find that redlining is associated with negative housing sale price effects, but the results are largely insignificant when accounting for flooding inundation.

Key Words: redlining, environmental justice, urban flooding

Model Estimated Nitrogen Emissions from Corn Fields under Different Fertilizer and Irrigation Management

Lizzie Long, Oklahoma State University (M. Foltz, J. Warren)

The use of nitrogen (N) fertilizers has allowed for increases in agricultural productivity. Excess N can leach into groundwater, runoff to surface water, or be emitted to the atmosphere as nitrous oxide (N_2O). High N levels in water have environmental and human health impacts, and N_2O in the atmosphere contributes to global climate change and stratospheric ozone depletion. N losses to water and the atmosphere can be modeled using the Denitrification-Decomposition (DNDC) model or simple emission factor estimates. The Testing Ag Performance Solutions (TAPS) program is a low-stakes competition in the U.S. Great Plains that encourages participants to be more efficient with their fertilizer and irrigation management. The most sustainable management scenario will be the fertilizer and irrigation combination that has the lowest total N losses with minimal impact on yield. Although yields have been monitored for past competitions, greenhouse gases like N_2O have not previously been measured or modeled. The objectives of this study were to (i) estimate and compare N losses to water (as nitrate) and air (as N_2O) from TAPS fields under different managements and estimation methods, and (ii) identify the most sustainable management scenario. Fields with differing amounts of fertilizer and irrigation were modeled and the model was then calibrated based on the average measured yield. The N_2O emissions range from 1.4-5.5 kg N/ha before calibration and 1.2-4.9 kg N/ha after calibration, with improved yield estimates after calibration. Emission factor estimates predicted lower N_2O emissions than the DNDC model. Future work should include field measurements of N_2O for comparison with model estimates. Overall, sustainable management practices are needed to prolong the availability of groundwater resources in the U.S. Great Plains and reduce harmful effects from the excess use of nitrogen and irrigation water.

Investigating the Possible Factors Causing the Increase of Salinity Levels in the Carrizo-Wilcox Aquifer, Winter Garden Region

Fabian Maldonado, Texas A&M University Kingsville (M. Alexander, J. Amaya)

The Carrizo-Wilcox aquifer is one of the most prolific groundwater sources found within Texas, spanning 66 Texas counties between the border of Mexico and the border of Louisiana. The strata of the aquifer consist mainly of clay, cross-bedded river sand, beach sand, silt, and lignite. The aquifer yields are fresh to slightly saline water, which is why the aquifer is the primary groundwater source for meeting irrigation, public supply, and industrial needs. Groundwater development within the Carrizo-Wilcox aquifer began in the early 1900s, when irrigation pumpage was widespread in the southern region of the aquifer, with the first flowing artesian well drilled in Dimmit County in 1884. Over the years, groundwater pumpage depleted aquifer storage, most notably in the south region of the aquifer, due to pumpage being far more common in the Winter Garden region. In recent years, oil and gas (O&G) operations have increased in the Winter Garden region of the aquifer as the Eagle Ford Shale has become one of the primary producers of O&G in Texas. Due to the Winter Garden's location, there is a higher percentage of carbonate, which makes the aquifer shallower and more brittle. These conditions favor hydraulic fracturing, which involves the high-pressure injection of fluids into a wellbore to crack underground rock formations, allowing O&G to flow freely for extraction. As a result, fracking fluids create large amounts of wastewater and contain toxic contaminants that can leak and contaminate the groundwater and increase the salinity level within the aquifer. One of the primary objectives of this project is to create a MODFLOW groundwater fate and transport model of the Carrizo-Wilcox aquifer to show the impact of possible oil and gas operational leaks in the Eagle Ford Shale in the Winter Garden region, where the aquifer has experienced an increase in salinity levels.

Assessment of Atmospheric Deposition in Arkansas and Tennessee

Anna Grace McCarty, Arkansas Water Resources Center

Atmospheric deposition has likely changed with the influence of increasing global temperatures and subsequent changes in precipitation across the United States and world. The objective of this project was to analyze atmospheric deposition across northern Arkansas and Tennessee. The three specific objectives were to: a) evaluate trends in atmospheric deposition of various elements, b) assess the relationship between atmospheric deposition and rainfall, and c) evaluate if rainfall adjusted atmospheric deposition is changing over time. The data was from the National Atmospheric Deposition Program (NADP) website with the data ranging 1980 to 2022. Water and rainfall depth were collected from Fayetteville (site AR27) and sent to the NADP central lab for chemical analysis. Six sites have been analyzed, including AR16, AR27, TN00, TN04, TN11, and TN14, which span over northern Arkansas across Tennessee. The Kendall Tau (T) test has been used to evaluate changes in atmospheric deposition over time at annual and monthly scales. Deposition and rainfall relations were explored to determine which statistical model fits the data best through curve fitting with linear, exponential, quadratic, and locally-weighted regression. Atmospheric deposition was adjusted for rainfall using the difference of the observed data and the predicted data, and the rainfall adjusted depositional load was evaluated for changes over time.

Evaluation of Winter Flooding as a Management Practice for Mitigating Boron Toxicity in Almond Orchards

Felix Ogunmokun, University of California Davis (G. Osterman, M. Zapata, X. Li, F. Nicola, K. Ward, I. Kisekka)

Boron (B) is an essential micronutrient required by plants for cell wall development, plant growth, pollination, and seed formation. Due to its immobility in plants, B availability in soil is critical to plant growth. While B exists in various forms in the soil, only between 1-2% of the total B is soluble and available for plant uptake. However, at high concentrations in soil, B can become toxic to plants. Almonds (*Prunis dulcis*) are sensitive to high B concentrations in soil which can result in reduction of shoot growth, reduced tissue extension, chlorosis, dieback, sticky exudates and tree death. The objective of this study was to evaluate the effectiveness of winter flooding as a best management practice for leaching Boron from the root zone of almond trees. The study was conducted in a large commercial almond orchard in the Sacramento Valley of California with a history of B toxicity. The orchard was divided in two. One half was flooded in addition to seasonal irrigation, and another half was not flooded. Soil pore-water samples at various depths were taken bi-weekly for evaluation of B levels in the soil. Neutron probe data together with Terros-12 sensors were used to quantify soil moisture, temperature, and EC within and below the root zone. Also, periodic electrical resistivity tomography (ERT) and soil EC surveys were conducted to assess the advancement of the wetting front and spatial distribution of EC, respectively. Preliminary results indicate that flooding has the potential to leach soluble B out of the soil rootzone and allow almond trees to achieve their maximum growth and production potential.

Spatiotemporal Characteristics of Soil Moisture in Texas, United States: A Complex Network Analysis

Victor Oladoja, Kansas State University (T. Jamali, B. Ghanbarian)

Analyzing the spatiotemporal variability of soil moisture (SM) and its complex behavior is essential to manage agriculture and other natural resources more efficiently. It also helps improve forecasting short- and long-term climatic conditions and understanding of extreme events, such as floods and drought. This study employs concepts of complex network theory to analyze the topological structure and spatiotemporal dependency of SM in Texas. At first, we determine a similarity matrix between the SM time series of gridded daily observed SM data using time warp edit distance. The SM dataset for 16 years from January 2006 to December 2021 at 0.25^0 by 0.25^0 spatial resolution is obtained from the European Space Agency database. Then, the SM complex network is constructed based on the similarity matrix and using a threshold that results in a network with only statistically significant links. The network's degree distribution deviates significantly from the Poisson distribution, the degree distribution of a special class of random networks, which is a measure of no information; hence, complex network theory is a suitable tool to study the SM network. Furthermore, other network measures such as betweenness centrality, clustering coefficient, and community detection are expected to reveal more features of the SM network and its covariation regions in Texas. Our study reveals the spatiotemporal pattern of SM in the state of Texas that provides the base to better understand interactions between soil moisture and other climate components, particularly the local and non-local impacts of soil moisture anomalies on agriculture and ecosystems.

Do Managers of Dams with Greater Purpose Complexity Deviate Further from Rule Curves?

William Ottenheimer, Washington State University

There are inherent tradeoffs in the way dams process water both temporally and spatially as they store it or pass it downstream. Rule curves are the primary management tool for formalizing priorities over the competing objectives such as flood control, navigation, hydroelectricity, water supply, irrigation, recreation, fish/wildlife, water quality and low flow augmentation. Management complexity has increased greatly over the last fifty years as the total number of purposes placed on many dams has increased. Research has shown that managers of many U.S. Army Corp of Engineer (USACE) dams deviate significantly from rule curves (Patterson and Doyle, 2018). In this research we test the hypothesis that deviations are greater on dams with more operating purposes after controlling for other factors. Our data includes the water level attainment, rule curve prescription, and number of operating purposes for 260 dams over 50 years, the average available history of these dams. We normalize each dam's departure from their target. Further descriptive data recognizes the type of target water level, uniform or varying, and the division of the USACE overseeing each dam because management. Our results reveal a negative relationship between target attainment and additional purposes of dams. This can be interpreted as dams with more operating purposes are more likely to deviate from formal targets than dams with fewer. An additional discovery is the significant correlation of each management division on the overall adherence to the targets which alludes to the presence of differentiated strategies, environmental/stakeholder concerns, or information across regions.

Cover Crops Affect Irrigation Water Use in Cotton

Carson Roberts, Mississippi State University (D. Gholson, M. Locke, D. Spencer, B. Pieralisi, W. Crow, N. Quintana)

Improved cropping systems are needed to reduce irrigation water use of cotton where irrigation water is drawn from the declining Mississippi River Valley Alluvial Aquifer. A study conducted in Stoneville, MS, from 2021 to 2023 is assessing viable cropping systems for the mid-south to conserve irrigation water. Study treatments were established in the fall of 2020 and include reduced tillage, subsoil, winter fallow (RT); strip till, winter fallow; strip till, cover crop; strip till, subsoil, cover crop; no till, winter fallow; no till, cover crop; and no till, minimal surface disturbance subsoil, cover crop. Each treatment was individually irrigated based on tension-based soil moisture status. In the first year of full study implementation (2021), high amounts of timely rainfall made irrigation unneeded. In 2022 precipitation was closer to normal. Cover crops improved soil moisture by as much as 47 kPa compared to the conventional, RT treatment. Compared to all winter fallow treatments, the treatments with a cover crop retained more soil moisture with soil moisture tension being 57% lower. This resulted in more irrigation water used in treatments with winter fallow. There were few differences in lint yield between the treatments, and yields were not improved by increased irrigation. Cover crops can be used to conserve water in cotton without reducing yield in the mid-south during years with normal precipitation.

Examining the Right-of-Way Process for Navajo Nation USA Indian Allotment Lands in Connection to the Navajo-Gallup Water Supply Project

Bernadette Romero-Benally, New Mexico State University

Today, there are 573 Indian nations across the USA. Each nation has its own history relating to Indian allotment lands. This research examines the administrative Right-of-Way process for the Great Navajo Nation Indian allotment lands by applying a real example of its connection to the Navajo-Gallup Water Supply Project. A Project that involves two federal sister agencies and Navajo allottees. The Project's Right-of-Way process is initiated by the Bureau of Reclamation through the Bureau of Indian Affairs, who will either approve or disapprove the Right-of-Way easement.

One must understand the research questions. What is a Right-of-Way? What are Indian allotment lands? What is the Navajo-Gallup Water Supply Project? How do these three concepts connect to one another? The examination began by working with the Bureau of Reclamation, the Bureau of Indian Affairs and the Navajo communities impacted by the Project. One research finding is that the Bureau of Indian Affairs has the authority over the Navajo allotment lands, not the tribe. The construction of the Project was approved by a recent Navajo Nation San Juan River Water Rights Settlement. The surface water is the San Juan River located near the Four Corners in New Mexico. Another finding is that Indian allotments is deeply rooted into a federal Indian policy known as the General Allotment Act of 1887.

Both the Navajo allotment lands and water access is questionable. We learned that the current Right-of-Way process for the Navajo allotment land is quite general. We also learned that the Project pipeline alignment will cross six types of land status. Each type has its own Right-of-Way process. After examination, the research provides recommendations about how to improve the current Right-of-Way process by creating a better framework to help us better understand the Right-of-Way process for Navajo allotment lands. Lessons learned from this research has the potential to guide policy makers, tribal leaders, Indian allottees, and any economic developer about the Right-of-Way issues found on Navajo allotment lands that impacts project delays, schedules and the cost of a water pipeline project. Today, there are more and more Indian water right settlements being settled across the USA, this research recommends for nations, tribes, and pueblos to include the Indian allotment lands and Indian allottees.

Evaluation of Wetland Treatment to Improve Discharge to Baffin Bay

Kaitlyn Smith, Texas A&M University-Kingsville

Natural and man-made wetlands used in wastewater treatment need optimized construction for efficient contaminant removal. Wetlands are commonly used as nutrient sinks and buffering sites for the removal of pollutants in wastewater. They are largely passive systems that achieve the treatment of wastewater through physical, chemical, and biological processes. Several factors influence the efficiency at which contaminants are removed such as detention time, rainfall, evapotranspiration, and temperature.

The City of Bishop Texas has a simple detention pond system that is used to treat municipal wastewater, before discharging into a creek that leads to Baffin Bay. Baffin Bay provides high economic potential to Texas and large recreational space, thus contaminated wastewater entering that area is of concern. The focus of this research is to analyze the discharge rates of Bishop wetlands and their sulfate, nitrate and lead levels. These contaminants can be mitigated by wetlands downstream of the Bishop pond treatment system. This process of contaminant removal can be characterized as chemical reactions that break down the compounds. This is through the denitrification of nitrate to produce nitrogen gas and reducing sulfate to hydrogen sulfide. This behavior can be quantified using rate law equations. The lead can be absorbed through water ferns and sediments, so it is no longer transported through the water. The wetlands will be considered an open channel, non-ideal plug flow reactor. This will be shown through hydrodynamic equations for unsteady free-surface flow and first order temperature dependent kinetics. Some modifications may need to be done where parts of the wetlands may behave more as a CSTR (continuous stirred-tank reactor) and other parts behave as a PFR (plug flow reactor).

Impacts of Intensifying a Corn-Soybean Rotation with Winter Wheat on Nitrate Leaching in Southern Illinois

Abigail Spiers, Southern Illinois University Carbondale (K. Williard, A. Sadeghpour, J. Schoonover, J. Snyder, J. Gillespie)

The Midwestern United States is a globally important producer of agricultural products, and intensive agriculture is a significant contributor to nutrient export in the Mississippi River Basin and the hypoxic zone in the Gulf of Mexico. Winter cover crops can be a tool to help decrease nutrient leaching and provide other benefits to water and soil quality; however, a limiting factor to the widespread adoption of cover cropping is the associated costs. Crop intensification, or double cropping, may provide similar benefits associated with having a winter ground cover while also adding a second source of income. A plot scale study was established at Southern Illinois University Carbondale's Agronomy Center to evaluate the effects of high, medium, and low fertilizer treatments in corn-soybean rotations that include winter wheat as a double crop, cereal rye as a cover crop, and no winter ground cover. Preliminary study results will be presented at the conference.

Quantifying the Impact of Climate Change and Land Use Change on Water Quality in the Nanticoke River Watershed

Avalokita Tuladhar, Colorado State University (R. Bailey, S. Abbas, J. Arnold, M. White)

Nutrient pollution in the Chesapeake Bay is on an ongoing issue that requires extensive analysis, planning, and management. Climate change is expected to increase precipitation and extreme weather events, resulting in increased runoff that carries more nutrients from the land into the water, as well as higher water temperatures and reduced dissolved oxygen levels. Land use change, urbanization, and agricultural activities, such as the use of fertilizers and manure, are major sources of nutrient pollution in the watershed, leading to increased runoff and nutrient influx. In this study, we use an integrated hydro-chemical modeling approach to quantify the impact of future climate and land use change on water quality (nitrate NO_3, phosphorus P concentrations, and loads) in the Nanticoke River watershed, which discharges to the Chesapeake Bay. Doing so can provide insights that can aid in the implementation of effective measures to decrease nutrient pollution and preserve the Chesapeake Bay and its environment. To fulfill our objective, we use the watershed modeling code SWAT+, augmented with a physically based spatially distributed groundwater model using the new *gwflow* module, calibrated and tested for the Nanticoke watershed using observed streamflow, groundwater head, and in-stream loadings of NO_3 and P. The model accounts for water and nutrient fluxes in all major hydrologic pathways (surface runoff, percolation, soil lateral flow, recharge to the aquifer, tile drainage, groundwater pumping, irrigation, groundwater-stream exchange, and stream flow). The calibrated model is applied to future scenarios using downscaled CMIP5 Global Climate models for future weather and the DynaCLUE model for predicted future land use, to quantify the effect of climate and land use changes on nutrient storage and transport throughout the watershed system, with a focus on changes in in-stream nutrient loadings.

Drilling Deep Observation Wells in Carbonate Island Karst – The Monitoring System Expansion and Rehabilitation Program, Guam

Maria Jhonnie Villareal, Water and Environmental Research Institute of the Western Pacific (WERI) (J. Jenson, K. Bautista)

The Monitoring System Expansion and Rehabilitation Project (MSERP), from January 2021 through December 2022, rehabilitated 7 existing Deep Observation Wells (DOWs) and added 7 more to the fleet of wells that measure the response of the aquifer to variations in recharge of the Northern Guam Lens Aquifer (NGLA). The initial 7 DOW's were installed to collect hydrological data from 3 (out of 6) major groundwater-producing basins of the NGLA. The addition of 7 new wells aims to augment hydrologic data collection to include other basins that are lacking monitoring wells. The data collected from these wells are utilized in various studies and evaluation of seasonal and long-term changes in rainfall, groundwater levels, and salinity that support growth and sustainable groundwater production in Guam. The 7 new additional wells were designed and drilled with three objectives in mind, (1) be deep enough to extend through the bottom of the freshwater lens; (2) have sufficient inside diameter to accommodate instrumentation; and (3) allow free movement of groundwater for accurate and timely measurements. The drilling works itself was the perfect opportunity to collect scientific data derived from cuttings, water level depths, conductivity profiles, video logs, and borehole geophysical survey. As expected, drilling in carbonate island karst was no easy feat due to the inherent heterogeneity of karst in the subsurface. We purposefully collected, documented and characterized important karst features as they were encountered and experienced during drilling. Challenges encountered, difficulties resolved, and the lessons learned in drilling DOW's in carbonate island karst are presented in this work.

Keywords: karst drilling, carbonate island karst, karst hydrogeology

Analysis of Discharge Locations for Corpus Christi Desalination Plants

Ilde Vivero, Texas A&M University - Kingsville

Since the 2011 South Texas drought, the Coastal Bend has been looking for sustainable water supply. Corpus Christi is the regional water planner, producer, and distributor for the Coastal Bend, providing water to more than 500,000 people. The City of Corpus Christi (CCC) has proposed two desalination plants as possible solutions for a sustainable water supply, one located in La Quinta Channel and the other one in Inner Harbor. Meanwhile, the Port of Corpus Christi Authority (PCCA) has designated Harbor Island and La Quinta Channel as proposed desalination plant discharge locations. An analysis of the discharge location is crucial - it is important to understand the potential impact of the brine (and other metals used in the process) and how it will affect its surrounding areas; the concerns prompt us to consider other locations for the discharge. A viable alternative in the area is the diffusion method, which consists of a pipe running through the seafloor to efficiently mix the brine with the seawater; a great advantage of resorting to the Gulf of Mexico is its strong currents, larger diffusion area and low salinity counts. By using datasets compiled by the Gulf of Mexico Ocean Observation (GCOOS), information such as latitude, longitude, salinity, density, depth and velocity from delimited hexagonal areas (30 kilometers in length) from the Gulf of Mexico were obtained. A series of calculations were performed to obtain water quality-based values for salinity to compare it against the effluent limits published by CCC and PCCA. According to the findings, it would be beneficial for the Coastal Bend to have the planned desalination plants locate their discharge location deeper into the Gulf of Mexico rather than in active fishing and shipping sites such as the Corpus Christi Ship Bay, Nueces Bay, and the overall Coastal Bend regional water system.

Keywords: Desalination, Water, Sustainable, Discharge Locations, Coastal Bend.