FY 2020 Annual Report
National Program 211 - Water Availability and Watershed Management

Introduction

Fresh water is essential to maintaining both agricultural and industrial production, ecosystem integrity, and human health. Throughout history, a key measure of civilization's success has been the degree to which human ingenuity has harnessed freshwater resources for the public good.

As the Nation was established and expanded, it flourished in part because of abundant and readily available water and other natural resources. With expansion to the arid west, investments in the use of limited water resources became critical to economic growth and prosperity. In the 19th century, water supplies for new cities were secured by building reservoirs and water distribution systems. The 20th century was characterized by pivotal accomplishments in U.S. water resource development and engineering. Investments in dams, water infrastructure, irrigation, and water treatment provided safe, abundant, and inexpensive sources of drinking water, aided flood management and soil conservation, created recreational opportunities for the public, and dramatically improved hygiene, health, and economic prosperity. The Nation's water resources and water technologies were the envy of the world. Certainly, water-related science and technology had served our Nation well. However, the 20th century was also characterized by significant increases in irrigated area, fertilizer use, and improved crop genetics that combined to produce explosive growth in agricultural production as the Nation became a major exporter of agricultural products. Concurrently, agriculture became the largest consumptive user of freshwater, but possibly the least understood in terms of opportunities for conserving water supplies and improving water quality for all users.

As the 20th century drew to a close, the water resource situation in both the United States and the world began to change. Runoff and drainage from heavily fertilized fields increasingly affected the aquatic health of our waterways and oceans. Key groundwater reserves began to become depleted, water quality became increasingly degraded, and adverse climatic conditions (e.g., drought) began to significantly reduce available freshwater supplies. At the same time, freshwater allocations began to shift among different users and needs (e.g., from agricultural to urban uses; from storing water supplies in reservoirs to maintaining in-stream flows to ensure healthy aquatic ecosystems; from industrial and energy production to recreation). Our shared freshwater supply was significantly reduced as it also became more variable, unreliable, and with increasing frequency, less than adequate to meet the needs and demands of an expanding population. Meanwhile, large-scale and complex water quality issues began to impact the Gulf of Mexico, Chesapeake Bay, and the Great Lakes. Clearly, new technologies were needed to allow agriculture to better manage both water quantity and quality.

As the 21st century unfolds, these new challenges for agriculture are intensifying—increasing demands for water from our cities, farms, and aquatic ecosystems; increasing reliance in the eastern humid and sub-humid states on irrigated agriculture for stable crop and animal production and farm income; changing water supplies due to groundwater depletion in some areas; climate variability and change; and the need to tap alternative water resources. These challenges are not insurmountable, and in terms of their impacts on both water supply and use and water quality, agricultural lands can play an important role in meeting them. Advances in agricultural water management can provide important and unique contributions to the complex problem of water management at regional and national scales. Science and engineering can create new and emerging technologies that widen the range and effectiveness of options for future water management; and science can develop and provide the tools needed by managers and planners to accurately predict the outcomes of proposed water management decisions at farm to national scales. The factual basis for decision-making includes an understanding of these new technologies, their effectiveness as well as potential unintended consequences, and a strategy for getting water users and agencies to adopt the technologies determined to be most effective. Thus the Nation has the opportunity to apply and use science and technology to protect, sustain, enhance, and manage our water resources, improving human and ecological health while continuing to build a strong and growing economy.

The USDA-ARS National Program for Water Availability and Watershed Management (NP211) had a productive and dynamic year in 2020. Scientists in NP211 continue to make extraordinary impact in numerous diverse areas of research relating to global root-zone soil moisture monitoring, mitigating phosphorus losses from tile-drained landscapes, and publishing landmark historical data sets as part of the Long-Term Agro-ecosystem Research (LTAR) network.

NP 211 addresses the highest priorities for agricultural water management (effective water management; erosion, sedimentation, and water quality protection; enhancing and documenting the benefits of conservation practices; and watershed management to improve ecosystem services in agricultural landscapes). Research will also be conducted to determine the transport and fate of potential contaminants (sediments, nutrients, pesticides, pathogens, pharmaceutically active and other organic chemicals, and salts and trace elements) as well as to assess our capabilities to conserve and reuse waters in both urban and agricultural landscapes and watersheds.

Specific topics to be studied include: irrigation scheduling technologies for sustainability; drainage water management and control; field scale processes controlling soil erosion and the transport and fate of sediment and contaminants; understanding how to select, place, and combine conservation practices to achieve improvements in water quantity and quality in watersheds; improving conservation technologies to better protect water resources; ensuring conservation and agricultural management practices can increase agricultural profitability and resilience under changing climate and land use; development of tools and methods to improve water resource management; and improving watershed management and ecosystem services through large area, long-term field research, site characterization, and data dissemination in agricultural watersheds and landscapes. The overall goal is to provide solutions to problems in the utilization of the Nation's water resources.

NP 211 is organized into four Components:
• Effective Water Management in Agriculture
• Erosion, Sedimentation, and Water Quality Protection
• Enhancing and Documenting the Benefits of Conservation Practices
• Watershed Management to Improve Ecosystem Services in Agricultural Landscapes

During FY 2020, 134 full-time scientists working at 26 locations across the United States actively engaged in 33 ARS-led and 285 cooperative research projects in NP211. Base funding for the program was $79M.

Personnel news for NP 211

New additions to the NP211 team in 2020 are:

- **Dr. Scott Bradford** previously of the U.S. Salinity Laboratory, Riverside, CA, is the Research Leader of the new Sustainable Agricultural Water Systems Research unit in Davis, CA.
- **Dr. Brent Dalzell** joined the Soil and Water Management Unit in St. Paul, MN. Dr. Dalzell received his Ph.D. from Purdue University, followed by post-doctoral research at Old Dominion University and the University of Minnesota. His research interests are in watershed hydrology and soil biogeochemistry, with specific expertise in water quality modeling and dissolved organic matter transport.
- **Dr. Ken Wacha** was hired as a Research Agricultural Engineer at the National Soil Erosion Research Laboratory, W. Lafayette, IN. Prior to joining NSERL, Ken was an ORISE fellow with the National Laboratory for Agriculture and the Environment (NLAE) at Ames, IA. Dr. Wacha is studying how management practices impact the delivery of ecosystem services, including soil physical quality/health, organic matter, surface hydrology and upland erosion.

- **Dr. Dave Millar** was hired as an Agricultural Engineer in the Pasture Systems and Watershed Management Research Unit in East Wareham, MA. He will be developing a research program on precision agriculture in cranberry production with emphasis on irrigation and fertilizer management.
- The Southeast Watershed Research Lab in Tifton, GA welcomed the following new personnel in 2020: **Dr. Rachel Nifong** joined SEWRL as a Research Hydrologist. Dr. Nifong is a former ARS postdoctoral associate at the National Sedimentation Lab in Oxford, MS, and came to SEWRL from the U.S. Army Corps of Engineers where she served as a Biologist/Project Manager. Dr. Nifong earned her Ph.D. in Hydrologic Sciences at the University of FL in 2015. In addition to research on hydrologic processes, Dr. Nifong will be conducting research on the spatial and temporal aspects of water availability and links to trace gas fluxes in the southeastern coastal plain. **Dr. Kathryn (Katie) Pisarello** accepted a position as a Research Soil Scientist. Dr. Pisarello earned her Ph.D. in Soil and Water Sciences at the University of FL in 2019. She will be conducting research integrating crop, population biology, economic, watershed, ecosystem services, social and risk assessment models to quantify economic, environmental and production tradeoffs for the Gulf Atlantic Coastal Plain LTAR site and will work with the LTAR Modeling Team to compare economic, environmental, and production tradeoffs among major crop production regions across the LTAR network. **Mr. Earl Keel** was hired as a Hydrologist with the SEWRL. Prior to this position Mr. Keel was a Computational Biologist with the Watershed Lab. Mr. Keel will be providing oversight to the SEWRL's hydrologic and environmental studies and assisting in data processing. **Dr. Haile Tadesse** joined SEWRL as a Physical Scientist. Dr. Tadesse worked for the Environmental Protection Agency as a Postdoctoral Fellow in the ORISE program, and prior to that with ARS as a Physical Science Technician in El Reno, OK. Dr. Tadesse earned his Ph.D. in Environmental Science and Public Policy from George Mason University. He also holds a professional certification in Geographic Information Science from George Mason University. Dr. Tadesse will be supporting research on cropping systems and water use efficiency in the southeastern U.S. using remote sensing and GIS.
- **Dr. Eric Billman** started as a Research Agronomist at the Coastal Plains Soil, Water, and Plant Conservation Research Center, Florence, SC in June 2020. Eric received his Ph.D. in Agronomy from Mississippi State University in 2018, focusing on plant breeding in forage crops. Dr. Billman's current duties with ARS at Florence will leverage his background in plant genetics and abiotic stress tolerance in the South to develop novel drought stress and cover cropping strategies for the cotton production system in the southeastern U.S.
- **Dr. Curtis Ransom** was hired as a Research Soil Scientist at the Cropping Systems and Water Quality Research Unit in Columbia, MO. Dr. Ransom received a Ph.D. from University of Missouri. His research will focus on Big Data, Artificial Intelligence, and machine learning for agronomic decision support.

- The Water Management Research Unit at Parlier, CA welcomed the following new scientists in FY20: **Dr. Kelley Drechsler** joined as a support scientist/agricultural engineer. Before joining ARS, she was a graduate student at UC Davis. Her thesis research focused on irrigation and improving water use efficiency in almonds. **Dr. Pedro Lima** joined WMRU as an engineering technician. Before joining ARS, Pedro was a research support staff member at UC Davis. His background is in crop water use and agricultural engineering. **Natalie Scott** joined WMRU as a Biological Sciences Technician. Before joining ARS, Natalie worked at the University of Alberta and Bard College. Her research background is in root and soil associated microorganisms. **Aileen Hendratna** joined WMRU as a Biological Sciences Technician. Her research background is in environmental chemistry including greenhouse gas emissions.
- The Great Plains Agroclimate and Natural Resources Unit, El Reno, OK, welcomed two new scientists in FY20: **Dr. Tugba Yildirim** is a postdoctoral research associate hired to use available climate and remote sensing data to develop a tool to help producers make informed agricultural production decisions under increasingly variable climate and climate change. **Dr. Lifeng Yuan** is currently working on quantifying the impact of climate change, especially storm intensification, on surface runoff, soil erosion, and crop production under various cropping and tillage systems in central Oklahoma using computer models. The in-house climate downscaling software of GPCC and SYNTOR is used to downscale future climate changes under three greenhouse gases emission scenarios, and the impacts of climate change are evaluated using the WEPP model.
- **Dr. Amanda Nelson** joined the Sustainable Water Management Research Unit, Stoneville MS as a Research Hydrologist in 2020; her research focuses on soil and water conservation, and agroecosystem management. **Dr. Rajen Bajgain** also joined SWMRU as a postdoctoral research associate studying micro-meteorology, and carbon and energy fluxes of ecosystems.
- The U.S. Salinity Laboratory, Riverside, CA welcomed two new postdoctoral research associates in FY20: **Dr. Thedor Bughici** received his Ph.D. from the Ben-Gurion University of the Negev, Israel. Dr. Bughici's expertise is modeling soil hydrologic processes and evapotranspiration in irrigated systems. He is currently working on optimizing drip irrigation practices for water conservation and salinity control. **Dr. Mario Guevara** completed his Ph.D. at the University of Delaware. Dr. Guevara's expertise is digital soil mapping and statistical learning. He is currently working on methods for developing broad-scale maps of soil salinity and other soil properties using remote, proximal, and *in situ* sensing data.
- **Dr. Ravindra Dwivedi** joined the Southwest Watershed Research Center, Tucson AZ, as a postdoctoral research associate, to work with Research Hydrologist Joel Biederman on precision vegetation management to conserve and enhance snow water supplies. Ravindra specializes in hydrologic modeling of the critical zone, the layer of Earth extending form the

tops of vegetation through the land surface and through the root zone to bedrock. Ravindra is currently using laser maps of forests and snowpack to model vegetation management impacts on snowmelt volume and timing.

The following scientists left the ranks of NP211 in 2020:

- **Dr. Danny Marks** retired from the Northwest Watershed Research Center in Boise, ID. In recent years, Danny worked closely with the NASA Jet Propulsion Laboratory to create the Airborne Snow Observatory (ASO) program to combine remote sensing data acquisitions with high-density, large-scale computer modeling to provide improved near real-time snow water storage estimates for the entire southern Sierra Nevada mountains**.**
- **Dr. John Sadler,** Soil Scientist and Research Leader of the Cropping Systems and Water Quality Research Unit in Columbia, MO, retired after 36 years with ARS. John is well known for his leadership within CEAP and LTAR and was ARS Senior Scientist of the Year in 2016.
- **Dr. Jurgen Garbrecht** retired from the Great Plains Agroclimate and Natural Resources Unit, El Reno, OK, on December 31, 2019.
- **Dr. JR Rigby,** Research Hydrologist, left the Watershed Physical Processes Research Unit, Oxford, MS, to join USGS in 2020. Dr. Rigby had been with ARS since 2011 working on critical groundwater and aquifer recharge issues in the Lower Mississippi River Basin.

The distinguished record of service of these scientists is recognized worldwide; they will be missed in NP211.

The following scientists in NP 211 received prominent awards in 2020:

- Scientists in the Hydrology and Remote Sensing Laboratory in Beltsville, MD, received the following awards in FY20: **Dr. Martha Anderson** was elected as a Fellow of the American Meteorological Society in FY20. Dr. Anderson also received the USDA REE Undersecretary award for “significant and impactful research on remote sensing of vegetation water use and stress in agroecosystems” and was the ARS Northeast Area Senior Scientist of the Year. **Dr. Michael Cosh** was elected a Fellow of the American Society of Agronomy. Dr. o Wade Crow: Received the “Robert E. Horton Lecturer” Award from the American Meteorological Society “for developing data analysis techniques that enabled important advances in the scientific and operational application of terrestrial remote sensing products.” **Dr. Bill Kustas** received the AGU 2019 Hydrologic Sciences Award for “outstanding contributions to the science of hydrology.”
- **Dr. Brad King** of the Northwest Irrigation & Soils Research Laboratory, Kimberly ID, received the American Society of Agricultural and Biological Engineers (ASABE) Heermann Sprinkler

Irrigation Award this year. The award recognizes engineering excellence in the design, evaluation, operation, or management of sprinkler irrigation systems.

- **Dr. Sherry Hunt** of the Hydraulic Engineering Research Unit, Stillwater, OK, received Meeting Council Special Recognition for Completing a Two-year Term as the first Society Wide Technical Program Chair from the American Society of Agricultural and Biological Engineers at their Annual International Meeting.
- Scientists from the Conservation and Production Research Laboratory in Bushland TX (**Drs. Susan O'Shaughnessy, Steve Evett** and **Paul Colaizzi**) led a team that included **Dr. Earl Vories** of the Cropping Systems and Water Quality Research Unit in Columbia MO, **Dr. Ken Stone** of the Coastal Plain Soil, Water and Plant Conservation Research Unit in Florence SC, and **Dr. Ruixiu Sui** of the Sustainable Water Management Research Unit, Stoneville MS; the team's project "Sensor Based Variable Rate Irrigation Control Increases Crop Water Productivity" was awarded the 2020 Excellence in Technology Transfer Award and Technology Focus Awards from the Federal Laboratory Consortium, and the 2020 Vanguard Award from the Irrigation Association.
- **Dr. Michele Reba** of the DWM Research Unit, Jonesboro AR, received the 2020 USA Rice Sustainability Award for her leadership and innovative research around sustainable rice production. Her specialties in civil engineering and hydrology make her unique in the rice research world, but what truly sets her apart is her ability to bring together university professors, ARS researchers, crop consultants, and farmers to work on some of the most difficult research questions around water use in rice. Dr. Reba was also part of a team (including **Drs. Joseph Massey, Arlene Adviento-Borbe**, and **Yin-Lin Jack Chiu**)that received the 2020 Conservation Innovation Award for their contribution to the Rice Irrigation Water Management Field Day Team during the 75th Soil Water Conservation Society International Annual Conference. The field day is held annually and highlights innovative farming practices at the field and farm scale that is focused on reducing agriculture's environmental impacts while protecting crop yield and profit.
- Scientists from the Great Plains Agroclimate and Natural Resources Unit, El Reno, OK, received these awards in 2020: **Dr. Jean Steiner** (retired) received the 2020 Hugh Hammond Bennet Award from the Soil and Water Conservation Society; **Dr. Daniel Moriasi** received the 2020 the Journal of Soil and Water Conservation Associate Editor Excellence Award; and **Dr. Amanda Nelson**'s (former postdoctoral research associate at the GPANRU) publication describing data from WRE watersheds was one of two articles selected for promotion in the CSA News Magazine - the official magazine for members of ASA, CSSA, and SSS.
- **Dr. Newell Kitchen** of the Cropping Systems and Water Quality Research Unit in Columbia, MO, received the Werner L. Nelson Award for Diagnosis of Yield-Limiting Factors from the American Society of Agronomy.

- **Dr. Veronica Acosta-Martinez** of the Wind Erosion & Water Conservation Laboratory, Lubbock, TX, was awarded the 2020 Purdue University Distinguished Agriculture Alumni Award.

In 2020, a number of factors demonstrated the quality and impact of NP 211 research:

- Publication of 323 peer-reviewed journal articles;
- 14 new interagency agreements initiated;
- 1 new patent application, a further invention disclosure, and 2 new material transfer agreements; and
- 132 students and postdoctoral research associates training with ARS; 25 student-directed outreach activities reaching about 1,055 students

In 2020, NP 211 scientists collaborated with scientists in Australia, Austria, Belgium, Bolivia, Brazil, Cambodia, Canada, Chile, China, Czech Republic, Denmark, Ecuador, Egypt, England, Ethiopia, France, Germany, Greece, Greenland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Lebanon, Mexico, Netherlands, Pakistan, Peru, South Korea, Spain, Switzerland, Taiwan, Turkey, Uruguay, and Vietnam.

NP 211 Accomplishments for FY2020

This section summarizes significant and high impact research results that address specific components of the FY 2016-2020 action plan for NP 211. Each section summarizes accomplishments of individual research projects in NP 211. Many of the programs summarized for FY 2020 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA-ARS research by rapidly disseminating technology, enhancing the impact of ARS research programs.

Effective Water Management in Agriculture

Selected Accomplishments

Deficit irrigation saves water in peach production under arid conditions. Agricultural irrigation is a major user of fresh water in arid and semiarid areas of the world. About 23,000 hectares of peaches grown in the Central Valley of California depend on irrigation, which uses scarce water resources. Deficit irrigation is a potential strategy to save water without severely impacting crop production; however, the long-term impact of deficit irrigation on productivity is not well understood. ARS researchers in Parlier, CA, demonstrated in a 10-year field study that deficit irrigation can result in up to 40 percent water savings without significant yield losses or reductions in fruit quality such as firmness, total soluble solids, pH, malic acid, or total phenolics. Findings from this long-term research provide peach growers an alternative irrigation strategy to save water and lower input costs.

Center pivot mounted leaf temperature sensors are inexpensive and provide accurate input to irrigation water optimization. In times of low crop prices, farmers need to produce crops as inexpensively as possible. One way farmers can reduce input costs is to irrigate only when it is most needed. Crop leaf temperatures are easily measured by sensors, which provide a real-time assessment of water stress, and in turn, indicate if irrigation should be scheduled. However, users of temperature sensors have been concerned that measurements from sensors mounted on a center pivot may not be as accurate as non-moving (stationary) sensors. ARS scientists in Bushland, TX, compared irrigation scheduling based on data from stationary temperature sensors to those mounted on a center pivot. There were no differences in accuracy between stationary or moving temperature sensors, and irrigation application scheduling governed by one type of sensor was similar to scheduling governed by the other. Center pivots are now used on 30 million acres in the United States. Installing temperature sensors aboard center pivots and using them for irrigation scheduling could save farmers substantial water and reduce energy input costs.

Soil and leaf sensors improve irrigation scheduling for water conservation. Because of limited water resources on the Texas High Plains, producers are interested in growing grain sorghum, which requires less water than corn to produce maximum yields. However, precision irrigation scheduling tools are needed to optimize regional sorghum production. ARS scientists in Bushland, TX, in collaboration with the Rural Development Administration of South Korea and University of Nevada at Reno, have used automated irrigation scheduling based on leaf canopy temperature with and without data from soil moisture sensors to manage grain sorghum at high, medium, and low irrigation levels. The scientists found that plant and soil water sensing with multiple stress thresholds and several different irrigation volumes led to the most water efficient irrigation management for grain sorghum producers in Texas. The methods achieving the highest water use efficiency were readily automated. Irrigators implementing such a system will save time, use less energy, and reduce groundwater withdrawals.

Late planted corn requires less irrigation water. Because of declining water levels in the Southern Ogallala Aquifer region, alternative management strategies are needed to reduce groundwater withdrawals while maintaining profitable crop yields. Delayed planting of corn on the Texas High Plains is believed to reduce irrigation requirements by taking advantage of increased precipitation and reduced evapotranspiration demand. However, limited field data exist for corn planting dates in the region. ARS researchers at Bushland, TX, and Texas A&M AgriLife used a calibrated Soil Water Assessment Tool (SWAT) model with long-term historical climate data to simulate corn irrigation and yields for both long and short season corn varieties. Simulation results suggested that irrigation requirements of short season corn were at least 25 percent lower than requirements for long season corn, while grain yields decreased by less than 9 percent. Data from field experiments conducted in 2016 and 2017 with drought tolerant corn hybrids corroborated these trends. These results indicate that the delayed planting of corn combined with effective irrigation management have the potential to reduce groundwater withdrawals from the Ogallala Aquifer. These results are useful to irrigators as a means of extending their groundwater resources and reducing their energy input costs.

Sub-surface drip reduces seasonal irrigation applications for corn. In the face of declining water supplies, crop farmers need to maximize the yield per unit of water used in crop production, the so-called crop water productivity (CWP). It is not well understood how irrigation application methods affect CWP. ARS scientists in Bushland, TX, compared the water use and yield of grain corn and sorghum production using sprinkler and subsurface drip irrigation (SDI) methods. Using the SDI application method, loss of water to evaporation was reduced by 2-5 inches during the growing season, compared to losses that occurred with sprinkler irrigation. SDI reduced overall corn water use by up to 6 inches and increased grain yields by up to 20 percent. The combined effects were an increase in CWP by up to 46 percent, compared with sprinkler irrigation. The increases in CWP are enough to offset the higher costs for SDI installation.

Alternative crops grown in saline soils provide value-added products. Drought-, salt-, and boron-tolerant plant species that are adapted to grow with high saline drainage or ground waters in poor-quality soils are valuable commodities in the western United States. ARS researchers in Parlier, CA, are testing the viability of several specialty crops in saline drainage sediment and in saline/boron soils in the San Joaquin Valley. They are irrigating salt- and boron-tolerant poplar-tree clones, Opuntia cactus, guayule, mustard, agretti, and pistachio with drainage waters containing high levels of salt, boron, and selenium. All tested plants and trees produced selenium-enriched plant products, and guayule produced increased amounts of latex and resin under saline conditions. The successful use of alternative drought-, salt-, and boron-tolerant crops and the production of new biobased products provide growers new agronomic strategies and alternative crops for continuing production in drainage-impacted regions of the western Central Valley of California.

Erosion, Sedimentation, and Water Quality Protection

Selected Accomplishments

Terrestrial sources of urea shown to contribute more than urea fertilizer to toxic algal blooms. Global increases in the frequency and toxicity of algal blooms in coastal waters are raising concerns over agricultural use of urea, the most common form of commercial nitrogen (N) fertilizer. ARS researchers in University Park, PA, with colleagues from the University of Maryland-Eastern Shore and Penn State University, evaluated urea transport in field drainage, runoff, and stream water within an agricultural basin on Maryland's Atlantic Coastal Plain. Results showed that runoff of recently applied urea in early spring is usually diluted below levels of environmental concern. However, in summer, stagnant water in small field ditches and wetlands creates ideal conditions for microbial production of urea that flushes into local streams and subsequently flows to coastal waters. Producers can manage drainage control structures to allow ditches to drain freely during summer. This will minimize the development of stagnant water pools, which will greatly reduce the risk of harmful algal blooms due to urea flushing from agricultural drainage ditches into streams and coastal waters.

Long-term dataset demonstrates value of native cover in protecting water quality. Long-term research is important to understanding how land management affects runoff and erosion in agricultural production systems. ARS scientists have compiled, discussed, and published 23 years of historical data measured in 8 fields located in El Reno, OK. Results indicated that native tallgrass prairie fields had 98 percent, 72 percent, and 78 percent lower suspended sediments, total soluble phosphorus, and nitrate-nitrogen losses, respectively, than cropped fields. This research database is essential for determining the impact of different agricultural management systems, understanding the processes related to hydrologic transport and water quality, and the development and validation of the corresponding models. These data contribute to national initiatives, including the Long-Term Agroecosystem Research network and the Conservation Effects Assessment Project, that are working to quantify the effects of land management on soil and water resources under variable climate.

Method for partitioning deisopropylatrazine in streams. Streams within the Salt River Basin of northeastern Missouri are chronically contaminated with the triazine herbicides atrazine and simazine, and their common metabolite deisopropylatrazine (DIA). However, in order to link stream pesticide levels to herbicides applied in the fields, one needs to know the parent source of DIA. Therefore, a method is needed to partition DIA between its two parent sources – i.e., DIA derived from atrazine (DIAATR) and DIA derived from simazine (DIASIM). ARS scientists in Columbia, MO, along with University of Missouri cooperators, developed a method based on the concentration ratios of simazine to atrazine (SAR) in streams. The SAR method performed better than two other methods based on concentrations of chloro-triazines in field runoff. The SAR method results demonstrated the differences in DIASIM and DIAATR transport timing, with peak DIASIM transport occurring from mid-November to April and peak DIAATR transport from May to June. In the Salt River Basin, dual-season triazine applications substantially increased the period of high chloro-triazine concentrations in streams from approximately 3 to 8 months per year. This new method provides water resources and conservation managers the means to identify the parent herbicide and target conservation efforts toward its management in order to improve water quality.

Semiarid grassland nitrous oxide emissions increase with warmer temperatures. Although much climate change research focuses on carbon dioxide, there are other important greenhouse gases occurring in smaller quantities, but with greater potency than carbon dioxide, including nitrous oxide (N_2O). ARS researchers in Tucson, AZ, and colleagues from China analyzed 46 published studies worldwide in which temperature or precipitation were artificially altered to test for effects on N_2O emissions. They found that increased temperature drove increased N_2O release from soils by an average of 33 percent, although the results varied across biomes, with the biggest response in shrublands. Increased precipitation also enhanced N_2O emissions, while reduced precipitation suppressed emissions. Collectively, these results suggest that globally warming temperatures may increase N_2O release, representing a reinforcing effect on climate change in the future.

Modified blind inlets structure design improves dissolved phosphorus removal. Blind inlets, which are limestone-gravel filters for agricultural drainage water in field depressions, were shown to be effective at reducing losses of particulate phosphorous (P) (i.e., P bound to sediment) by virtue of sediment filtration. However, typical blind inlets are ineffective at removing dissolved P, which is a greater water quality hazard than particulate P. ARS scientists in West Lafayette, IN, improved a blind inlet by constructing it with steel slag, a material that has a high affinity for dissolved P, and monitoring for impact on water quality. Over a 3-year period, the use of steel slag removed 45 percent of the dissolved P, 18 percent of the organic nitrogen, 67 percent of the ammonium, and 70 percent of the glyphosate and dicamba from field runoff. Steel slag costs for blind inlets are similar to the costs of aggregates and provide a simple update for improving removal of dissolved P and some pesticides. The benefit to growers is that it reduces their negative impact on water quality and increases production sustainability by preventing the loss of nutrients and pesticides.

Mapping of manuresheds helps improve manure nutrient utilization and the environment. Nutrient recycling is fundamental to sustainable agricultural systems. Few mechanisms exist, however, to ensure that surplus manure nutrients from confined animal feeding operations (CAFOs) are effectively transported for use in nutrient-deficient croplands. These nutrients sometimes concentrate in locations where they can threaten environmental health and devalue manure as a fertilizer. As part of the LTAR research effort, an ARS team from multiple locations, led by scientists in Las Cruces, NM, classified the 3,109 counties of the contiguous United States by their capacity to either supply manure P and N or assimilate and remove excess P and N via crops ("sinks"). ARS scientists in St. Paul, MN, assisted in the analysis and are co-leading a follow-up effort focusing on the dairy component of manure production and use. Manuresheds—areas surrounding livestock operations where excess manure nutrients can be recycled for agricultural production—differed in the transport distances needed to assimilate excess manure P based upon the type of CAFO (from 147 ± 51 km for a beef-dominated manureshed to 368 ± 140 km for a poultry-dominated manureshed). This highlighted the need for systems-level strategies that operate across local, county, regional, and national scales to promote manure nutrient recycling. This LTAR approach is now being applied to each animal segment (dairy, hog, beef, poultry) at the national level to close the loop between animal manure production and plant nutrient needs, which will reduce contamination of ground and surface waters in animal production regions.

Enhancing and Documenting the Benefits of Conservation Practices

Selected Accomplishments

Effective nitrate removal from tile drained fields in Iowa using saturated riparian buffers. The saturated riparian buffer is a conservation practice that diverts agricultural tile drainage into streamside soils, which can effectively remove nitrate from drainage water at little cost. Conservation planners want to understand the potential role of this practice in addressing nitrate losses from agricultural watersheds with tile drained cropland. ARS scientists in Ames, IA, applied the Agricultural Conservation Planning Framework (ACPF) in 32 Iowa watersheds to determine the extent of riparian zones suited for saturated buffers, and the extent of tile drained lands found above those same riparian zones. Riparian lengths suited to the saturated buffer practice occupied 30-70 percent of streambanks in most watersheds and could treat tile drainage from 15 to 40 percent of the watershed areas. Saturated buffers have an important potential role for water quality improvement in many tile drained watersheds in Iowa and to a lesser extent where riparian practice options are limited. These results are useful for conservation planners seeking to identify viable options to reduce nitrate loads from Midwestern agricultural watersheds.

Assessing RUSLE2 and WEPP differences as a conservation planning tool. To streamline delivery of conservation assistance to farmers, the USDA Natural Resources Conservation Service (NRCS) plans to transition from the Revised Universal Soil Loss Equation 2 (RUSLE2) to the Water Erosion Prediction Project (WEPP) to guide conservation planning regarding erosion by water. However, there are concerns that estimated erosion rates may increase as a result of the transition, thereby adversely impacting farmers' conservation compliance. ARS researchers in Oxford, MS (RUSLE2 Team), and West Lafayette, IN (WEPP Team), conducted almost 40,000 simulations covering different climate, soil, land management, terrain, and crop yield conditions for counties in Illinois and Iowa. The soil loss estimates for about half of the simulation scenarios were statistically different between RUSLE2 and WEPP. In comparable scenarios, the primary differences were related to model soil erodibility characterization, slope length effects, no-till management, and cover crop managements. WEPP was sensitive to the quality of climate inputs, so future work should include comprehensive evaluations of different climate scenarios, as well as data precision, gaps, and resolution. The performed assessment is vital to conservation management planning provided by NRCS and farmer's conservation compliance under specific provisions of the 2018 Farm Bill.

A new modeling approach for soil and gully erosion research. A new 2D numerical simulation model has been developed by ARS researchers in Oxford, MS, to simulate soil erosion and gully erosion processes in field sized watersheds. This physically based model mimics rainstorm induced watershed runoff, splash erosion, shear erosion of soil, and sediment transport processes in high resolution. The simulation results were validated using experimental and field observation results collected by Federal agencies. This new capability helps hydrology and agriculture engineers in erosion control research and provides the NRCS a powerful tool (http://websim.rusle2.org), that will help evaluate ephemeral erosion throughout the country.

A long-term solution for thirsty crops. A cost-effective means of increasing plant-available water can alleviate water stress from infrequent precipitation or limited irrigation supplies. Polymer hydrogels increase the capacity of soil to hold water, but the effects were previously thought to last only a few years. ARS researchers in Kimberly, ID, conducted a 9-year study to measure the effects of a single hydrogel application on plant-available water in soil. Based on the slow decline in water availability seen in this study, the water retention benefits of hydrogels should last from 24 years to 29 years, considerably longer than current industry estimates. The long-term water retention benefits substantially increase the cost effectiveness for farmers applying hydrogels to improve soil's water holding capacity.

Watershed Management to Improve Ecosystem Services in Agricultural Landscapes

Selected Accomplishments

New water budgets across the Long-Term Agroecosystem Research (LTAR) network. Management of intensified agricultural production and climate can affect soil water storage and water movement in agricultural landscapes. Understanding these relationships is critical to more efficient and sustainable water use. ARS scientists in Columbia, MO, along with collaborators at all 18 LTAR sites, have developed agricultural site water budgets that account for all inputs and outputs of water on an average annual basis. The LTAR network covers a wide range of values for yearly precipitation, evaporation, plant water uptake, surface runoff, and subsurface flow. The LTAR modeling group is using these water budgets to validate their models across the network.

Adaptive nutrient management demonstrates enhanced economic and environmental outcomes. With increasing variability in climatic and economic drivers, producers who have previously used static agricultural management strategies may want to pursue adaptive management principles to improve net returns and potentially other ecosystem services. ARS researchers at Temple, TX, managed cropped fields in the Riesel Watersheds for 16 years using 0-8 tons of poultry litter per acre for their annual application rates. During this period, management progressed from static management to adaptive management using the Haney Soil Health Test, which reduced nitrogen application rates in fields with poultry litter applications and recommended cover crops. Using adaptive nutrient management reduced N application rates by 25 to 38 percent for low rates of poultry litter without sacrificing profitability. Poultry litter application rates in excess of crop phosphorus demand increased phosphorus runoff losses while reducing profitability. Long-term studies that analyze field-scale agronomic, economic, and environmental factors are extremely rare, since they are expensive and labor intensive. This LTAR study shows producers, conservation professionals, and policy makers the utility of adaptive management principles over the long-term as one potential suite of practices to balance economic and environmental outcomes through agronomic management.

Legume cover crop impacts on sugarcane production. Sugarcane is a commercially important crop in Louisiana, Florida, and Texas, and the sugar produced is worth over $1 billion (U.S.) annually. However, monoculture sugarcane production can degrade soils by reducing soil organic matter and enabling soil pathogenic microorganism proliferation. Cultural practices that improve sugarcane sustainability are thus needed to maintain yields in fields with degraded soils. Legumes can be grown to improve soil health during the normal fallow period between sugarcane crops. ARS scientists in Houma, LA, in collaboration with scientists at Louisiana State University AgCenter and Alma Plantation, completed multi-year and location trials that investigated how sunn hemp and cowpea cover crops affected subsequent sugarcane yields. On average, the cover crops provided 4.3 tons per acre of dry biomass, and 200 pounds per acre of nitrogen. Cowpea generally improved subsequent plant cane yields, but the effects of sunn hemp varied. However, neither cowpea nor sunn hemp reduced cane or sucrose yields consistently in subsequent sugarcane crops. Legume cover crops can be an important component of sustainable sugarcane production practices and are now being used by growers in several parishes in Louisiana.