

FY 2018 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 2018. 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 2018, 132 full-time scientists working at 25 locations across the United States actively engaged in 33 ARS-led and 266 cooperative research projects in NP211.

New additions to the NP211 team in 2018 are:

- **Dr. Kyle Douglas-Mankin** joined ARS as Research Leader of the Water Management and Systems Research Unit in Fort Collins, CO in 2018. Kyle served as a Hydrologist/Supervisory Research Hydrologist at the U.S. Geological Survey, New Mexico Water Science Center, Albuquerque, NM, since 2015. Prior to that, Kyle was a Senior Hydrologist on the U.S. Fish & Wildlife Service Everglades Program Team, Boynton Beach, FL, and an Professor in the Biological and Agricultural Engineering Department at Kansas State University, Manhattan, KS. Kyle's recent research focuses on complex watershed modeling and assessment studies, hydrologic impacts and uncertainty of climate change, ecohydrology, and representation of plant processes in hydrologic models at field to watershed scales.
- **Dr. Lauren Hale** joined the Water Management Research Unit, Parlier CA, as a Research Soil Scientist. She was previously a postdoc at the University of Oklahoma. Her area of research interest is on soil microbial community characterization as related to water management, soil health, and ecosystem functions.
- **Dr. Clement Sohoulade** has joined the Coastal Plain Soil, Water and Plant Conservation Research Unit in Florence SC, as a Research Agricultural Engineer with a background in water resources management. Clement's research interests include the use of physically-based and numerical models to quantify water and nutrients movement at both farm and watershed scales, remote sensing tools to enhance the prediction and mitigation of crop water stress and modelling the impact of manure treatment technologies in watersheds with a high density of livestock farms.
- **Dr. Anne-Marie Fortuna** joined the Grazinglands Research Laboratory, El Reno OK, as a Soil Scientist studying soil microbiology.
- Dr. John Zhang of the Grazinglands Research Laboratory, El Reno OK, hosted a visiting scientist, **Dr. June Liu**, from Shanxi Normal University, Xi'an, China, working on soil erosion.
- **Dr. Kyle Elkin**, a former ARS postdoc, joined the Pasture Systems & Watershed Management Research Unit at University Park PA, as a Chemist. Dr. Elkin provides specialized expertise in Liquid chromatography-mass spectrometry and inductively coupled plasma mass spectrometry.
- **Dr. Sanjeev Joshi** joined the Grazinglands Research Laboratory, El Reno OK, as a postdoctoral research associate (supervised by Dr. Jurgen Garbrecht) working on impacts of climate change/ variability on natural resources and agricultural productivity.

- **Dr. Brittany Hanrahan** joined the Soil Drainage Research Unit in Columbus OH, as a postdoctoral research associate. Her expertise is biogeochemistry and she is working on defining and understanding the relationships between crop and animal production agriculture and water quality to address the harmful algal bloom issues in Western Lake Erie Basin.
- The Watershed Physical Processes Research Unit in Oxford, MS hosted two visiting scientists in 2018: **Dr. Junguang Wang**, Associate Professor at Huazhong Agricultural University, China conducted research on the detachment and transport of soil aggregates in channels and soil pipes. **Dr. Fabian Rivera**, Professor at Universidad Juárez Autónoma de Tabasco, Mexico conducted research on meander bend cutoff dynamics along the White River, AR.
- The Water Quality and Ecology Research Unit in Oxford MI also hosted two visiting scientists: **Dr. Claudio Spadotto**, Empresa Brasileira de Pesquisa Agropecuária (Embrapa), Campinas/SP, Brazil, to evaluate pesticide modeling, and **Aline Zaffani**, graduate student, Sciences of Environmental Engineering Program at the São Carlos Engineering School of the São Paulo University (Brazil), to study pesticide mobility in soil.
- **Dr. Gan Sun**, a visiting scientist from Chinese Academy of Science, joined the Water Management Research Unit, Parlier CA for an 8-month sabbatical to work on applications of thermal infrared remote sensing to delineate water stress in tree crops in the 2019 growing season.
- **Dr. Xingang Liu** of the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing China, visited the Soil and Water Management Research Unit in St. Paul MN, to study herbicide sorption and degradation.
- The United States Salinity Laboratory, Riverside CA hosted the following visiting scientists and students in 2018: **Dr. Elia Scudiero**, a Research Agronomist at the University of California-Riverside, works in our group on soil and plant sensor instrumentation and related geospatial analyses; **Dr. Salini Sasidharan**, a postdoctoral research associate studying drywells and managed aquifer recharge; **Mireia Fontanet**, a PhD student from Polytechnic University of Barcelona, working on soil moisture sensors and precision irrigation scheduling; **Valerie Carranza**, a PhD student from University of California-Riverside, who is working on micrometeorological measurements of greenhouse gases and ET from animal manure lagoons; **Emem Akpan**, an MS student from Cal State Long Beach working on chemical treatments to minimize clay release and clogging in drywells; **Nathan Summerville**, an MS student from California State Long Beach working on modeling clogging processes in drywells; and **Christopher Cabanas**, an undergraduate student from University of California-Riverside that is helping with drywell field preparations.
- The Grassland Soil and Water Research Laboratory, Temple TX, hosted two visiting scientists in 2018: **Dr. Anne van Griensven** from Vrije University, Brussels, Belgium, and **Dr. Christoph Schulz** with the University of Natural Resources and Life Sciences, Vienna, Austria.

The following scientists left the ranks of NP211 in 2018:

- **Dr. Martin Shipitalo** of the Agroecosystems Management Research Unit in Ames IA retired in June 2018.
- **Dr. James Ayars**, Research Agricultural Engineer, retired from the Water Management Research Unit, Parlier CA, after 38 years of federal service with the ARS. Dr. Ayars research focused on irrigation and drainage management in the arid and semi-arid conditions.
- **Dr. Gerald Buchleiter**, Agricultural Engineer for the Water Management and Systems Research Unit in Fort Collins CO, retired in 2018. Jerry had a long and fruitful career with Water Management, most recently serving several years as the Farm Manager for the Limited Irrigation Research Farm.

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 2018:

- The 2018 National Excellence in Multistate Research Award from the USDA National Institute of Food and Agriculture was presented to the group officially known as the North Central Extension Research Activities (NCERA) 217 Committee on Drainage Design and Management Practices to Improve Water Quality. The award was presented Nov. 11 at the 131st annual meeting of the Association of Public Land Grant Universities (APLU) in New Orleans. The NCERA-217 committee involves researchers and extension specialists from 13 states and the USDA Agricultural Research Service. Representing ARS was **Dr. Dan Jaynes**, a soil scientist at the Agroecosystems Management Research Unit in Ames IA.
- **Drs. Michele L. Reba, Joseph Massey, and M. Arlene Adviento-Borbe** of the Delta Water Management Research Unit, Jonesboro AR, were part of a team that received the 2018 RTWG Distinguished Rice Research and/or Education Team Award for "Advancing irrigation management practices to achieve sustainable intensification outcomes." This trio's team also won the 2018 American Society of Agricultural and Biological Engineering Annual International Meeting Educational Aids Blue Ribbon Competition for "Innovation in Rice Irrigation Will Help Reduce Aquifer Decline."
- **Dr. Kenneth Stone**, Research Agricultural Engineer with the Coastal Plain Soil, Water and Plant Conservation Research Unit in Florence SC, was awarded the 2018 Heermann Sprinkler Irrigation Award by the American Society of Agricultural and Biological Engineers (ASABE).
- **Dr. Todd Skaggs** of the United States Salinity Laboratory, Riverside CA, was elected fellow of the Soil Science Society of America in 2018.
- **Dr. Sherry Hunt** of the Hydraulic Engineering Research Unit, Stillwater OK, received the American Society of Agricultural and Biological Engineers (ASABE) Presidential Citation for chairing an ad-hoc committee for the society. The Hydraulic Engineering Research Unit also received recognition from the USDA-NRCS for providing support to their National State Conservation Engineers Meeting.

In 2018, a number of factors demonstrated the quality and impact of NP 211 research:

Publication of 347 refereed journal articles;
3 new patents issued and 1 new patent application; and
3 new material transfer agreements

In 2018, NP 211 scientists collaborated with scientists in Argentina, Australia, Austria, Belgium, Brazil, Cambodia, Canada, China, Colombia, Congo (Republic), Denmark, England, Ethiopia, France, Germany, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kenya, Mexico, Netherlands, Norway, Pakistan, Palestinian Territories, Peru, Philippines, South Korea, Spain, Sweden, Switzerland, Taiwan, Tunisia, Turkey, Uruguay, and Uzbekistan.

NP 211 Accomplishments for FY2018

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 2018 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

Windows Dam Analysis Modules (WinDAM) C adopted by worldwide leaders in dam safety. WinDAM C, a CCE-certified software, is a computational tool released in 2016 by ARS in cooperation with the USDA Natural Resources Conservation Service (NRCS) and Kansas State University. This decision support software is used by dam safety engineers in predicting potential dam breaches. The software incorporates algorithms developed by ARS scientists for predicting embankment dam failures from overtopping or internal erosion and includes breach outflow and breach timing estimates. Since its release, the software has been adopted by consulting engineers, academic researchers, and Federal agencies, including the U.S. Corps of Engineers, U.S. Bureau of Reclamation, NRCS, and the Tennessee Valley Authority. In FY18, ten countries across North America, South America, Europe, and Asia requested the software and the majority have incorporated WinDAM C into their educational and design analysis toolboxes. This technology is helping dam safety engineers prioritize the rehabilitation schedules for the aging U.S. embankment dams and levees. Dams built, evaluated (using WinDAM C), and maintained by USDA NRCS provide an estimated \$2.5 billion in annual benefits to producers, shippers, communities, and others. ARS and their collaborators are currently exploring options to use WinDAM C in developing early flood warning systems that can be used by emergency managers, city planners, and policy makers in establishing zoning regulations, developing flood inundation maps, and improving emergency action plans.

Managed deficit irrigation can save 6 inches of irrigation water per acre and boost yields. Development of sustainable and efficient irrigation strategies is a priority for agricultural producers faced with water shortages. Managed deficit irrigation is a promising management strategy for reducing water use; the crop is not fully irrigated, but greater irrigation is applied during grain set and early fill. However, experimental results are lacking for this strategy. ARS scientists in Bushland, Texas, collaborated with Texas A&M AgriLife Research and Extension Service to study managed deficit irrigation with grain sorghum. Yields from crops produced with managed deficit irrigation averaged 25 bushels per acre more than crops produced with deficit-irrigated sorghum and used only 1.5 inches of additional irrigation compared with nearly 8

inches with fully irrigated sorghum. If irrigation water availability is limited, managed deficit irrigation has significant advantages over deficit irrigation.

Real-time crop water stress index for precise irrigation of wine grapes. Wine grapes are intentionally water stressed to control canopy growth and induce desirable fruit quality, but few techniques are available to continuously monitor plant stress in real time. ARS scientists in Kimberly, Idaho, developed and used a cell phone-based system to continuously monitor canopy temperature, climatic conditions, soil water content, and irrigation application and to then calculate the crop water stress index. The resulting information is sent to a website where users can access the data they need to manage irrigation water application. The information system was installed in three commercial vineyards in southwestern Idaho, and two of the vineyard managers used the real-time information to make irrigation decisions. This technology allows vineyard managers to use real-time plant data to precisely manage irrigation, thereby reducing water use and improving grape quality.

Economic effects of strategic deficit irrigation on maize grain yield. In arid areas where agriculture depends on irrigation, various forms of deficit irrigation management have been used to achieve high yields with less water. ARS scientists in Fort Collins, Colorado, showed water savings of 15 to 17 percent with little effect on yield by applying moderate-deficit irrigation to maize plants during the late-vegetative stage (before flowering). Importantly, these late-vegetative deficit applications of water prevented dramatic yield losses if the water shortage occurred at the end of the season. Economic modeling revealed little benefit to producers of intentionally using deficit irrigation under current conditions of average prices for grain and water, but it also revealed that deficit irrigation during the late-vegetative stage would be economical in some regions where water is in high demand and lease prices are rising. Thus, although strategic deficit irrigation showed some (albeit limited) benefit for producing a maize crop with less water, the most important benefit to producers is the knowledge gained that crops must be protected against late-season water shortage and the conditions under which deficit irrigation may be desirable. This information will also benefit water conservation policymakers by providing economic data to help balance agricultural and municipal water interests.

Handheld device can estimate virus infection in irrigated wheat. Winter wheat is grown on approximately 3 million acres in the Texas High Plains region, one-third of which is irrigated. But the region is susceptible to wheat streak mosaic virus (WSMV), which is transmitted by the wheat curl mite. If a wheat plant is infected early in the season, it will yield little to nothing, and associated research has shown that wheat crops with high levels of infection should not continue to be irrigated. To help identify WSMV infection early in the spring, ARS scientists and engineers in Bushland, Texas, and Texas A&M AgriLife researchers demonstrated a hand-held meter can be used to detect different light wavelengths that indicate color within the plant; this information is then used to identify fields with high levels of infection that should not be irrigated. Early detection of WSMV through use of this new sensor will help wheat farmers reduce water waste and associated pumping costs.

Low-cost sensing device for collecting field data. The capabilities, flexibility, and low cost of the open-source Arduino and similar electronics platforms, coupled with new and inexpensive sensing devices, has enabled agricultural and water scientists to develop prototype monitoring systems to measure plant height, canopy temperature, and canopy multispectral reflectance. ARS scientists in Stoneville, Mississippi, developed a low-cost sensing device and mounted it onto an agricultural vehicle to collect georeferenced sensor measurements as the vehicle traveled through the field. The scientists are working to improve coordination between their new sensing device and global positioning system information with the goal of demonstrating how affordable open-source components can be used to develop more refined monitoring systems to collect agricultural field data.

Rice water use can be reduced 22 percent by good management coupled with irrigation innovations. Rice is an important crop in the Lower Mississippi River Valley (LMRV); however, it currently requires up to three times the amount of irrigation as soybean, cotton, and corn. The Mississippi River Valley alluvial aquifer is the primary source of irrigation in the LMRV and the water level is dropping. Efforts are ongoing to devise management practices that reduce irrigation use. Multiple-inlet rice irrigation uses plastic tubing to simultaneously deliver irrigation to all paddies of a rice field. This practice can reduce irrigation use by up to 25 percent compared with the standard practice of cascade flooding. ARS researchers in Jonesboro, Arkansas, have demonstrated that the irrigation savings achieved when using multiple-inlet rice irrigation depend heavily on a farmer's management style. Even without rainfall, multiple-inlet rice irrigation was found to reduce irrigation use by 22 percent relative to cascade flooding when irrigation was halted as soon as runoff occurred from a rice field. These results show that multiple-inlet rice irrigation saves water through a combination of improved application efficiency and rainfall capture.

Subsurface drainage pipes can be mapped using unstaffed aerial vehicles. Effective and efficient methods are needed for locating pre-existing drainage pipes to modify or repair subsurface drainage systems, and to assess environmental effects of drainage practices. ARS researchers in Columbus, Ohio, and the University of Tennessee used an unstaffed aerial vehicle (UAV) mounted with visible, near-infrared, and thermal infrared cameras to conduct a preliminary drainage pipe mapping case study at an Ohio farm field. The thermal infrared imagery successfully mapped 60 percent of the drainage pipes present within the field. Although more investigation is needed, thermal infrared imagery obtained by a UAV exhibits promise for drainage pipe mapping, which in turn will provide benefits for farmers and land improvement contractors involved with repairing/modifying subsurface drainage systems, while also helping research scientists and regulatory personnel assess the environmental risks of drainage practices within agricultural landscapes.

Erosion, Sedimentation, and Water Quality Protection

Selected Accomplishments

Antibiotic resistance genes and antibiotics can be transported off agricultural fields in subsurface drainage water. Antibiotic resistance is an increasing medical problem, and the effect of agricultural use of antibiotics on resistance in human pathogens is not clear. Previous reports have indicated elevated levels of antibiotic resistance genes (ARGs) in surface water and groundwater around confined animal feeding operations that administer antimicrobials, but little is known about how their transport from tile-drained fields amended with swine manure affects downstream environments. ARS scientists in Ames, Iowa, and Iowa State University collaborators found higher levels of two genes that confer resistance to antibiotics in tile drainage and river water in spring and fall following swine manure application. Approximately 840,000 swine are raised within the watershed. A companion study also documented the presence of two veterinary antibiotics. The study provides new information establishing that ARGs and antibiotics are being transported off farmed fields in drainage water. These findings provide new science-based information to improve our understanding of this problem.

Chemical application setbacks safeguard water quality. Management of turfgrass on golf courses and athletic fields often involves application of fertilizers and pesticides to maintain grass health and performance. Those products are often carried away from the area via rainfall runoff into neighboring surface waters, where they enhance algal blooms, promote eutrophication, and harm sensitive aquatic organisms and ecosystems. ARS researchers in Saint Paul, Minnesota, evaluated the effectiveness of applying these chemicals away from field edges to reduce the amount that runs off after a storm. Experiments with water-soluble tracer compounds confirmed that an increase in application setback distance by 6 meters resulted in a 43 percent reduction in the total amount of applied chemical transported by storm runoff to neighboring areas. Expanding the buffer area between turfgrass and adjacent properties will help groundskeepers design chemical application strategies that maximize environmental stewardship, and scientists and regulators who develop chemical transport and risk models.

Streambanks contribute the majority of sediment and phosphorus in streams. Eroding streambanks can be major sources of sediment and nutrients to streams, resulting in property loss and damaged aquatic habitats. ARS scientists in Columbia, Missouri, in a 4-year study, quantified streambank erosion and its contribution to sediment and phosphorus transport in two watersheds within the Central Claypan region in northeastern Missouri. Streambanks contributed an average of 83 percent of the stream sediment and accounted for 57 percent of total phosphorus exported from the two watersheds. These results, along with earlier studies showing that streambanks contributed 23 percent of the total nitrogen exported, clearly demonstrated the effect that bank erosion has on stream water quality. Streambank erosion likely will increase with larger runoff events from more severe storms resulting from climate change. Numerous methods have been developed for controlling streambank erosion, and this study indicates that improved management such as installing streambank stabilization in flood plains would improve water quality in this region.

Atrazine transport in karst terrain. The Pennyroyal Plateau is a karst sinkhole plain in south-central Kentucky with intensive row-crop agriculture. Water quality concerns include the seepage of agricultural herbicides into the groundwater and underground streams via sinkholes. ARS scientists in Columbia, Missouri, investigated the movement of a single application of the pesticide atrazine from a treated field to the water flowing within a cave adjacent to the field. Results showed that atrazine and two of its metabolites were present in every water sample over an 18-month period and levels remained elevated 15 months after application. Transport of atrazine and its metabolites to the cave accounted for approximately 1 percent of the applied atrazine, losses that were comparable to surface runoff losses in the Corn Belt. A year after application, atrazine and its metabolites showed very slow declines in concentration, demonstrating that transport would continue to occur over several years and result in consistent, long-term contamination of the deeper groundwater aquifer. This study benefits conservation agencies and growers by demonstrating the effect of atrazine leaching into karst aquifers and raising awareness for the need to implement management practices tailored to karst terrain.

Improved soil erodibility formulation. Recent enhancements to USDA soil erosion models employ more physical descriptions of erosion processes, which requires knowledge of soil properties, land use, land management, and hydrologic variables to calculate soil erodibility. ARS researchers in Oxford, Mississippi, tested three soils that ranged in clay and sand content to develop a prediction tool for agricultural erosion. The results suggest that soil erodibility is affected by the initiation of particle movement, clay content, and the void ratio, whereas results for critical shear stress testing suggest that silt, void ratio, and water potential best indicate the initiation of motion. These findings were recently successfully implemented within the Revised Universal Soil Loss Equation 2 (RUSLE2), which is used by USDA for conservation planning purposes.

Surface based vibration sensors map soil compaction with depth. Soil compaction induced by agricultural machinery can reduce crop yields in field areas where compaction becomes pronounced. The assessment and delineation of compacted soils and plow pans are needed to define tillage protocols and fertilizer application and irrigation schedules within a soil management plan. Researchers at the University of Mississippi, in collaboration with ARS researchers in Oxford, Mississippi, have developed a method using only surface-based vibration sensors to map the degree of soil compaction as a function of depth. The method sends vibrations into the soil and records them at various distances from the vibration source using ground surface sensors, where they produce images of the soil profile in much the same way that a sonogram can produce images of organs and tissues in the human body. This technique provides agricultural engineers and soil scientists with a nondestructive field mapping tool to assess soil compaction. Having prior knowledge of the spatial distribution of compacted soils may allow a more judicious use of fertilizers and water resources to increase crop yields.

Efficient nitrate recycling and re-use. Nitrate contamination of surface and ground waters is a serious problem in many agricultural regions. It is a human health risk and contributes to

eutrophication of fresh water and the Gulf of Mexico. Most mitigation efforts focus on denitrification through a process of encouraging microbes to convert nitrate to nitrogen gas. This is inherently wasteful because much energy is required for the initial manufacture of nitrogen fertilizer. A more efficient solution would be to develop methods to recycle nitrate for re-use. ARS scientists in St. Paul, Minnesota, have developed a system that can remove nitrate from contaminated water and concentrate it for re-use as fertilizer. The system runs on electricity from solar panels, so it is suitable for remote locations. A feasibility test was successfully conducted on a contaminated trout stream that has a nitrate concentration of more than 20 ppm (twice the EPA safety standard of 10 ppm). The system was able to remove an average of 42 percent of the nitrate from water passing through it, concentrating it in a tank that ultimately reached a concentration exceeding 500 ppm, which was subsequently used elsewhere as fertilizer. This approach could be used to recover nitrate from streams and contaminated wells, ponds, and lakes.

Application of mine drainage residuals for treating horticultural greenhouse waste water.

Excessive dissolved phosphorus transport occurs in agronomic cropping systems and horticultural operations. The presence of phosphorus contributes to the eutrophication of water bodies such as the Gulf of Mexico and Lake Erie. ARS researchers in West Lafayette, Indiana, constructed a phosphorus-removal structure in a greenhouse to filter dissolved phosphorus from the drainage water of pots. Ornamental, fruit, and vegetable plants were grown in traditional greenhouse media, and all drainage water from the pots was collected and filtered through a phosphorus sorption material (PSM) on a bed of mine drainage residuals (MDRs), which are a byproduct of treating acid mine drainage pollution from coal mines. The horticultural operation produced extremely high concentrations of dissolved phosphorus and elevated concentrations of copper and zinc. The PSM/MDR structure is still removing nearly 100 percent of phosphorus and copper after 1 year of operation, whereas much less zinc has been removed (cumulative removal approximately 25 percent). This study gives greenhouse managers a way to reduce the negative environmental effects of adding phosphorus to horticultural operations through use of these filters.

Biochar aging changes pesticide sorption, influencing pest control and environmental fate.

Water pollution from applied agrochemicals typically involves transport through the soil, where colloidal particles may play an important role in trapping them. Biochar, a carbon-rich soil amendment, can be useful for trapping agrochemicals, but its composition can change with environmental changes (freeze-thaw and wet-dry cycles), which may alter its trapping potential and have effects on water quality and the ecosystem. ARS researchers in Saint Paul, Minnesota, examined the effect of soil aging on an oak hardwood biochar that was buried in silt loam soil for 6 months. The soil-aged biochar sample absorbed significantly larger amounts (>85 percent) of all pesticides in the laboratory experiments compared with fresh biochar samples, which absorbed less than 15 percent. Both biochar samples had similar chemistries with no oxidation or chemical alterations observed after 6 months. These results show the variability of biochar absorption capacities and changes with time after its addition to soil, which will affect the environmental fate of applied pesticides and thus the possibilities for long-term control of pests. This information is significant to farmers and policymakers and will assist scientists and

engineers in understanding the potential alteration in the absorption potential for biochar once it is applied to soils.

Real-time decision support tool measures soil moisture and runoff potential. Producers need accurate predictions of soil moisture and surface runoff to gauge the best time to apply manure, fertilizer, and pesticide. The Real-time Conservation Effects Assessment Project (CEAP) model is a highly detailed, national-scale model that is aiding agricultural producers in timing their field operations. CEAP is a congressionally-mandated multiagency effort to evaluate the effects of current and past USDA conservation programs and potential future policies. CEAP uses a system of models and detailed climate, soils, landcover, and cropland management data for the contiguous United States to predict agricultural effects on water quality. This tool is leveraged by real-time CEAP data to make short-term future predictions of runoff and soil moisture. Climate data are updated each day with observed NEXRAD and National Weather Service 3-day forecasted precipitation. Simulations of 3 million units are performed each night on a high-performance server and summarized by county. Predicted soil moisture and surface runoff data are processed and interpreted into application advisories and warnings that are publicly available via the real-time CEAP website (<https://realtimeceap.brc.tamus.edu/>). Farmers are now using the CEAP model to better time pesticide and fertilizer applications to prevent losses in runoff.

Enhancing and Documenting the Benefits of Conservation Practices

Selected Accomplishments

Vegetated drainage ditches and retention ponds improve water quality. In intensive agricultural areas, agricultural best management practices are used to reduce suspended solids and nutrient loads and thus improve water quality, but more information is needed to effectively combine these practices. As part of the Conservation Effects Assessment Project (CEAP) watershed in the Mississippi Delta, ARS researchers in Oxford, Mississippi, collected measurements of sediment, nitrogen, and phosphorus draining through vegetated drainage ditches into a vegetated sediment pond from crop-cultivated areas. Vegetated drainage ditches combined with a vegetated sediment pond were effective in reducing sediment loads and moderately effective at reducing nutrient loads in runoff, resulting in an improvement in the water quality of agricultural runoff. These study results provide regulatory and other agencies and farming stakeholders with a practical way to combine conservation practices to improve and sustain water quality and overall environmental quality.

Watershed Management to Improve Ecosystem Services in Agricultural Landscapes

Selected Accomplishments

Geophysical techniques for assessing soil salinity across multiple scales. Knowing the salinity level within a field is valuable for individual producers to optimize their local production, whereas knowledge of salinity levels across hundreds of square miles is valuable to policymakers and decisionmakers at the state level. However, developing maps of soil salinity at any scale is a technological challenge because soils are highly variable in their properties, especially salinity. The compendium of work by an ARS scientist in Riverside, California, has resulted in an integrated salinity mapping system consisting of 1) a platform of ground and satellite sensors, 2) protocols and guidelines for mapping soil salinity, and 3) software for selecting sampling sites to calibrate sensors. The system gives stakeholders reliable, reproduceable, and accurate maps of soil salinity. Thanks to this new ARS-developed mapping system, it is now possible to determine soil salinity levels on a wide scale, include soil saline content as a factor in selecting suitable crops for production, and include soil salinity information in estimating potential agricultural revenue.

Automated data preparation for water supply forecasting. Having an accurate estimate of streamflow is intrinsic to water resource management for agriculture, flood control, drought management, power generation, and domestic water supply purposes. But producing accurate estimates of streamflow requires manually checking dams and other measuring devices, preparing data, and running water supply forecasting models. The staff time required to do this severely limits the use of current models, which are based on the physical processes of snowmelt and hydrology over a large area. To make part of this task easier, ARS scientists in Boise, Idaho, developed and implemented software called the Spatial Modeling for Resources Framework (SMRF) that makes it possible to apply physics-based hydrologic modeling in real-time to generate better streamflow estimates. SMRF now makes it feasible to transfer complex and sophisticated hydrologic models into a functional application that can be adapted for use across the entire western United States. SMRF is being tested by water supply forecasters at the California Department of Water Resources, the Natural Resources Conservation Service National Water and Climate Center, and the U.S. Bureau of Reclamation.