FY 2017 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 20st 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 2017. 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 2017, 133 full-time scientists working at 26 locations across the United States actively engaged in 35 ARS-led and 265 cooperative research projects in NP211. ARS-led projects were approved through the ARS Office of Scientific Quality Review in 2017, making this the first year of implementation of these five-year projects. The gross fiscal year 2017 funding for NP211 was $66 million.

New additions to the NP211 team in 2017 are:

- Research Hydrologist **Dr. Lindsey Yasarer** joined the Water Quality and Ecology Research Unit, Oxford MI. Dr. Yasarer was formerly a postdoctoral research associate at WQERU.
- **Dr. Eileen Kladivko** of Purdue University was a visiting scientist in 2017 at the National Laboratory for Agriculture and the Environment, Ames IA. Her work focused on cover crops, nutrient losses in subsurface drainage, and soil health.
- The Water Management Research Unit in Parlier CA hosted three visiting scientists in 2017: **Dr. Duan Yinghua** from the Chinese Academy of Agricultural Sciences, working on fertilizer use efficiency and water quality; **Dr. Wang Qiuxia** of the Chinese Academy of Agricultural Sciences, working on pesticide fate and transport and environmental quality; and **Dr. Claudio Pasqueul** from the University of Palermo, Italy, worked on selenium absorption and desorption on biochar.
- The Wind Erosion and Water Conservation Research Unit in Lubbock TX also had three visiting scientists in 2017: **Dr. Rende Wang** and **Dr. Chunping Chang** both hail from the Department of Earth Sciences, Hebei Normal University, Shijiazhuang, China, and studied wind erosion through laboratory wind-tunnel experiments. **Dr. Guo Ming Zhang** came from the Academy of Disaster Reduction & Emergency Management, Beijing Normal University, China, to perform wind erosion measurements in heterogeneous shrub communities and study robotic platforms for mobile sensors.
- The Hydrology and Remote Sensing Laboratory in Beltsville MD hosted two visiting scientists in 2017. **Professor Jie Cheng** is from the School of Geography, Beijing Normal University, and is conducting research on estimating evapotranspiration (ET) with thermal-based energy balance models developed by HRSL researchers over heterogeneous land surfaces in China and the United States **Dr. Fangni Lei** is from Wuhan University, Wuhan, China. Her expertise lies in the assimilation of remote sensing retrievals into hydrologic

models. She is currently working on the assimilation of high-resolution, thermal-based remote sensing information into a soil water balance model for improved irrigation management within vineyards. This work is contributing to the ongoing GRAPEX research project.

- **Dr. Rachel Nifong**, formerly at the University of Maryland, joined the Water Quality and Ecology Research Unit, Oxford MI as a postdoctoral research associate in 2017.
- **Dr. Scott Havens,** formerly of Boise State University, started as a postdoctoral research associate in the Watershed Management Research Unit, Boise ID. Dr. Havens is working on developing water supply forecasting technology as part of the NASA-JPL Airborne Snow Observatory (ASO) Program.
- **Dr. Amanda Cano,** a postdoctoral research associate at Texas Tech University**,** visited the Wind Erosion and Water Conservation Research Unit in Lubbock TX, to perform soil health assessments in the Ogallala aquifer.
- The Hydrology and Remote Sensing Laboratory in Beltsville MD hosted several doctoral and postdoctoral associates in 2017:   **Dr. Jianzhi Dong,** a postdoctoral research associate from the Delft University of Technology (Delft, Netherlands), works on the integration of soil moisture and temperature observations into land surface models. He is currently utilizing remotely-sensed soil moisture to improve our large-scale understanding of soil moisture/energy flux coupling along the land/atmosphere interface. **Dr. Tiffany Wilson** is working on integrating a water balance model specifically developed for vineyards with the remote sensing-based evapotranspiration modeling system developed by HRSL scientists for monitoring vineyard root zone soil moisture and vine stress for improved irrigation scheduling.   This work is contributing to the USDA-NASA funded GRAPEX project. **Rodnei Rizzo** is a PhD student from University of Sao Paulo, Brazil working on basin-scale water balance using remote sensing. **Panpan Yao** is working on her PhD with the Chinese Academy of Sciences on downscaling techniques to estimate soil moisture from the upcoming Water Cycle Observation Mission satellite.
- Hydrologist **Mark Kautz** joined the Southwest Watershed Research Center in Tucson AZ, to be the interface between the unit scientists and the field work on Walnut Gulch. Mark has a BS in Hydrology and MS in Watershed Management from the University of Arizona.

The following scientists left the ranks of NP211 in 2017:

- **Dr. Howard Skinner**, Plant Physiologist with the Pasture Systems and Watershed Management Research Unit, University Park PA, retired in 2017.
- **Dr. James Gerik** retired from the Water Management Research Unit in Parlier, CA.

- **Dr. Seth Dabney,** Research Leader of the Watershed Physical Processes Research Unit, Oxford MI, retired in 2017.
- **Dr. Gary Lehrsch** retired in January 2017 from the Northwest Irrigation & Soils Research Laboratory, Kimberly, ID
- **Dr. Don Suarez** retired in June 2017. He was the U.S. Salinity Laboratory Director and Research Leader of the Water Reuse and Remediation Research Unit in Riverside, CA.

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 2017:

- **Dr. Martha C. Anderson** of the Hydrology and Remote Sensing Laboratory, Beltsville MD was elected as a Fellow of the American Meteorological Society. Dr. Anderson has made major contributions to the science of satellite remote sensing of surface energy, water and carbon fluxes, has provided leadership to multidisciplinary and multinational teams addressing issues of food and water security.
- **Dr. Michael H. Cosh** of the Hydrology and Remote Sensing Laboratory, Beltsville MD received the Arthur S. Flemming Award in 2017: Dr. Cosh is known for his work on satellite remote sensing of soil moisture calibration and validation. He is a major contributor to NASA's Soil Moisture Active Passive Mission and ESA's Soil Moisture Ocean Salinity mission. His research led to a dataset for the verification of an essential climate variable. The application of this research includes improved weather and climate modeling and forecasting, basin-scale water accounting and improved monitoring and sustainability of agricultural water use in water-insecure regions.
- **Dr. Kurt Spokas** of the Soil & Water Management Unit, St. Paul MN, was named a Fellow in the Soil Science Society of America and in the American Society of Agronomy.
- **Dr. Howard Skinner** of the Pasture Systems and Watershed Management Research Unit, University Park PA, was recognized as a Fellow of the Crop Science Society of America in 2017.
- **Dr. Martin Locke** of the Water Quality and Ecology Research Unit, Oxford MI, was named a Fellow of the American Society of Agronomy.

- **Drs. Mark Tomer, David James and Sarah Porter** received a 2017 Technology Focus Award from the Federal Laboratory Consortium for their work on "Development and Transfer of the Agricultural Conservation Planning Framework."

(l-r Jerry Hatfield, Mark Tomer, Sarah Porter, and David James of the National Laboratory for Agriculture and the Environment, Ames IA)

- **Dr. Dave Goodrich** of the Southwest Watershed Research Center in Tucson AZ shared the EPA's Office of Research and Development Bronze Award for his contributions to the Connectivity Science Synthesis Team documenting the science behind the EPA's 2015 Clean Water Rule.
- The Rangeland Hydrology and Erosion Model (RHEM) team was awarded the 2017 Federal Award for Customer Service. This award annually recognizes, promotes, and rewards service excellence, professionalism, and outstanding achievements by federal employees, including teams working on initiatives with a direct impact on customers. The RHEM team (**Drs. Mark Nearing, Mariano Hernandez, Jason Williams, Gerardo Armendariz,** and **Dave Goodrich** of the Southwest Watershed Research Center in Tucson AZ, and **Dr. Mark Weltz** of the Great Basin Rangelands Research Unit in Reno, NV) was specifically recognized for outstanding innovation and teamwork in designing, producing, and transferring a new generation of rangeland hydrology and erosion prediction technology to user agencies.
- **Dr. Jason Taylor** of the Water Quality and Ecology Research Unit, Oxford MI was awarded ARS's Early Career Scientist of the Year for the Southeast Area.

- **Dr. Terry Howell**, retired Research Leader of the Conservation and Production Research Laboratory, Bushland TX, was inducted into the ARS Hall of Fame in 2017

In 2017, a number of factors demonstrated the quality and impact of NP 211 research:
- Publication of 300 refereed journal articles;
- 3 new invention disclosures and a new patent application filed;
- 3 new material transfer agreements

In 2017, 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 FY2017

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 2017 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

Innovation in rice irrigation management and cropping practices reduces water use and greenhouse gas emissions. Flooded rice systems contribute significantly to global non-CO_2 greenhouse gas (GHG) emissions. Intermittent rice flooding (also called alternate wetting and drying, AWD) may significantly reduce GHG emissions and irrigation water use, but this has not yet been proven. In the largest rice growing region in the United States, ARS scientists in Jonesboro, Arkansas, quantified H_2O and CO_2 emissions to show a direct relationship of these emissions to plant growth stage and production practices in a commercial field. Also, studies in fields managed using various schemes of nitrogen (N) fertilizer applications provided N_2O and CH_4 emissions data that were used to identify critical drivers of these GHGs in a crop production system. Quantification of these fluxes reduces uncertainty associated with emission factors and estimates of the contribution of fertilizer N to agricultural N_2O and CH_4 emissions. Another study found that intermittent flooding reduced irrigation water use by 20 to 70% relative to conventional (i.e., continuous) flooding, while rice yields remained largely unchanged. This work suggests that significant reductions in water use may be possible, which may help sustain rice production during periodic droughts that are becoming more common; and the work shows that irrigation management is a key component to GHG mitigation in rice.

Alternative crops for drought-, salt-, and boron-tolerance. Extreme drought conditions and stark reductions in precipitation and available water supplies have increased the importance of identifying drought-, salt-, and boron-tolerant plant species that are adapted to grow with high saline drainage or groundwaters. ARS researchers in Parlier California, conducted multi-year field trials in drainage sediment in the west side of the San Joaquin Valley of California using salt- and boron- tolerant mustard, poplar-tree clones, and Opuntia cactus in soils with high

levels of salinity, boron and selenium, or irrigation water with medium levels of salinity and boron. Because of the salinity and boron, cactus fruit yields ranged from 10 to 40 metric tons/ha and mustard seed yields ranged from 0.8 to 1.4 tons/acre, which is less than yields from crops produced in high quality soil with high quality water. Approximately 10-20% net reductions of selenium in the saline soil were accounted for in harvested plant material, and less than 10% was assumed to be lost by leaching (a smaller than usual amount because of minimal precipitation). The harvested mustard seed can be used as a selenium supplement in regions where diets are deficient in selenium. The use of drought-, salt-, and boron-tolerant crops shows promise as an alternative farming practice for growers who have limited high quality water in the western United States.

Improving nitrate removal using saturated buffers with tile drainage. Streamside buffers of vegetation are a proven practice for removing nitrate from both overland flow and shallow groundwater before it can enter surface waters. However, in landscapes with tile pipe drainage, most of the subsurface flow leaving farmers' fields passes through the buffers in tile pipes, leaving little opportunity for nitrate removal. ARS scientists in Ames, Iowa, and university cooperators showed that re-routing a fraction of field tile drainage through the riparian buffer as subsurface flow can remove hundreds of pounds of nitrate each year, keeping it out of surface waters. Saturated buffers have been adopted by USDA-Natural Resources Conservation Service (NRCS) as Conservation Management Practice Standard #604 and are now eligible for Environmental Quality Incentives Program (EQIP) funding across the Midwest. Research shows that the practice could be installed along thousands of miles of rivers in Iowa alone, leading to the potential removal of millions of pounds of nitrate from our Nation's surface waters.

Cover crops reduce nitrogen export to streams and rivers. Subsurface drainage under corn and soybean production in the United States Midwest contributes to excess N draining into the Mississippi River, and resultant hypoxia in the Gulf of Mexico. With projected increases in crop production and fertilizer N use, it is important to manage cropping systems to maximize yield while minimizing this N loss. Scientists from ARS laboratories in Ames, Iowa, and Fort Collins, Colorado, and cooperators in Müncheberg, Germany, added simulation of drain flow to the HERMES agricultural system model. The modified HERMES model was then tested using four years of field data from central Iowa fields in corn-soybean rotation, with winter rye as a cover crop (CC) and without winter rye (NCC). The modified model accurately simulated N loss to subsurface drainage under both CC and NCC, and the simulations agreed with field data showing that winter rye cover crops substantially reduce N loss to drainage. The use of this modified model will help improve agricultural management and reduce N transport to streams and rivers.

Lowering the cost of removing phosphate from agricultural drainage waters. Filter treatment systems containing synthetic goethite (iron oxyhydroxide) could be a viable means of capturing phosphate present in agricultural drainage waters, but goethite can be costly unless it can be regenerated for continual use. Laboratory and field drainage phosphate removal tests were conducted on synthetic goethite, and after use, the same material was regenerated using a sodium hydroxide flush. Laboratory treatment tests showed that both the original and regenerated goethite removed greater than 98% of the phosphate present in agricultural drainage waters. Field agricultural drainage water treatment tests showed that the original goethite removed 75% of the phosphate present, while the regenerated synthetic goethite removed 34%. This indicates that in a field setting, regeneration of synthetic goethite will likely require a two-step procedure that first uses a dilute acid wash to remove calcium phosphate precipitates followed by a sodium hydroxide flush to release any remaining adsorbed phosphate. Consequently, with employment of a refined regeneration process, filter treatment systems containing synthetic goethite could be a cost effective drainage water phosphate removal treatment.

Better soil spatial variability mapping tools aid action agencies and farm management at field to landscape scales. Soil spatial variability influences water flow and transport of nutrients, salinity, trace elements, and pesticides, which impact the environment and affect crop yield. State and federal action agencies involved with agricultural, natural resources, and environmental management have high need for a tool to more easily map important soil properties that affect management decisions. ARS scientists in Riverside, California, have revised, extended, and updated protocols for mapping soil spatial variability. The new protocols expand on the previous field-scale salinity mapping protocols in scale by including the landscape scale and mapped soil properties of water content, texture, bulk density, and organic matter. Geospatial measurements of apparent soil electrical conductivity measured by electromagnetic induction or electrical resistivity are used to direct soil sampling using two different statistical approaches. Their state-of-the-art methods for mapping soil spatial variability have direct applications in site-specific irrigation and crop management, providing inputs for solute transport models of the root zone, and assessing soil salinity and soil health. Many state, federal and international action agencies will benefit and the protocols also provide a tool for water and land resource managers, researchers, producers, agriculture consultants, and extension specialists.

New design practices for efficient subsurface drip irrigation. As water availability from the Ogallala Aquifer decreases, farmers are looking at installing the most water efficient irrigation systems. Yield per unit of applied water tends to be highest with subsurface drip irrigation (SDI) compared to other irrigation systems. However, SDI is a relatively new irrigation technology and

design features are still evolving. Therefore, ARS scientists in the Bushland, Texas Ogallala Aquifer Program from Kansas State University examined the applicability of fluid equations to the design of flush lines. The authors recommended that these modified equations be used with a standard fluid model to ensure reliability of improved flush line design for SDI systems.

Erosion, Sedimentation, and Water Quality Protection

Selected Accomplishments

Improvement in irrigation reservoir design lowers barriers to adoption. Irrigation reservoirs are used to substitute for groundwater resources for irrigation, but the levees surrounding the reservoirs are highly susceptible to erosion by wind-driven waves. The condition and characteristics of the levees around 148 irrigation reservoirs in Arkansas, such as presence of block-failures and amount of vegetation, were recorded by USDA-NRCS. ARS researchers at Oxford, Mississippi, performed detailed analyses of the data to find patterns in levee characteristics associated with damaged levees and loss of levee top-width. It was found that the most important factor was maximum fetch length (distance across the reservoir in the direction of the prevailing wind). Farmers and NRCS field personnel can use these results to help design or modify levees so that they are less susceptible to erosion, which lowers barriers to adoption of the practice and helps to protect groundwater resources.

Numerical simulation models accurately predict breaching process of earthen dams and levees. Earthen embankments are sometimes breached by overtopping flow from reservoirs or rivers, and may result in loss of life and property damages. ARS researchers in Oxford, Mississippi, developed numerical simulation technology to study this problem. Testing against data from large-scale physical embankment failure experiments showed that the developed computational models predict the breaching process accurately. These models can improve flood warning systems and help in the development of inundation maps and emergency action plans for floodplain managers and dam/levee engineers.

Enhancing and Documenting the Benefits of Conservation Practices

Selected Accomplishments

Phosphorus removal technology in a comprehensive volume. Excessive phosphorus (P) in agricultural drainage waters has caused environmental problems world-wide. Treatment technologies to remove P in a real-time setting require a combination of applied science and engineering in chemistry, material science, hydrology, and hydraulics. An ARS scientist at West Lafayette, Indiana recently published the first comprehensive book on the design and construction of P removal structures. This publication makes P removal technology more readily available to anyone who plans to build a system to minimize the excessive P problem.

Using a numerical model for simulating water flow and quality to assess consequences of flooding disasters. Water quality computer models are needed to more comprehensively study water quality problems covering large areas such as rivers, lakes and coastal environments. ARS researchers in Oxford, Mississippi developed a two-dimensional numerical model and tested it using measured data in Lake Pontchartrain, Louisiana, after the flood release from the Mississippi River into the lake. The model simulated water flow, sediment transport and algal biomass distributions. The simulated results were generally in good agreement with field observations provided by the U.S. Geological Survey and satellite imagery from NASA. The model provides a tool for U.S. EPA and State Departments of Environmental Quality to assess environmental disasters.

Expanded utility of agricultural conservation planning software and database. The Agricultural Conservation Planning Framework (ACPF) developed by ARS provides on-line data and software to assist NRCS and conservation partners in watershed planning efforts. But ACPF needed a database that more widely represented Midwest conditions. ARS scientists in Ames, Iowa, expanded the ACPF database to include more than 7,000 Midwest watersheds. Data for about 1,600 watersheds was accessed by ACPF users this year. Nearly 200 individuals representing federal, state, and county action agencies, universities, environmental and agricultural-commodity advocacies, and private engineering consultants have received training on use of the software in seven two-day training sessions. Among several improvements developed this year was a tool that identifies locations where riparian buffers can receive and treat drainage water via subsurface discharge. Statewide results were developed for Iowa that suggested about 14,000 miles of stream bank length may be suited to this inexpensive and passive treatment option for nitrate removal and water quality improvement. This utility of the ACPF tool illustrates the importance of new technologies in water management and planning.

Watershed Management to Improve Ecosystem Services in Agricultural Landscapes

Selected Accomplishments

Remote sensing toolkit provides first-ever daily delivery of crop water use data for irrigation and other water management at multiple scales. An important approach for effective agricultural water management is accurate measurement of crop water use (evapotranspiration or ET) at appropriate temporal and spatial scales. To address this need, ARS scientists in Beltsville, Maryland, developed and distributed a novel ET mapping toolkit based on the fusion of remote sensing data obtained from multiple satellite platforms. The fusion allows for the production of daily crop water use estimates at an unprecedented 30-m spatial resolution. Due to its significant resolution advantages, the toolkit has already been used to address many water resource issues in agriculture, including: groundwater depletion via irrigation in Central Wisconsin, the impact of expanding agricultural drainage on regional hydrology in the Corn Belt, water use in managed forest plantations, calibration of hydrologic/water quality models for the Chesapeake Bay Watershed, irrigation management decision making in vineyards, consumptive use assessments for the U.S. Water Census and California's new Sustainable Groundwater Management Act, and drought and water information delivery for the Near-East North African region. The toolkit will also be used to generate ET and water stress products for NASA's ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) mission. Through these projects, this ET mapping tool has greatly expanded our ability to monitor, and therefore optimize, water use and availability across a broad range of agricultural systems.

Improving satellite-based soil moisture monitoring for row-cropped regions of the Plains states. ARS scientists in Beltsville, Maryland, contributed to an international experiment completed in 2016 to verify accuracy of the NASA Soil Moisture Active/Passive (SMAP) satellite mission in the Red River Basin of the Northern Great Plains. A ground and aircraft measurement campaign was conducted in and around the South Fork Experimental Watershed near Iowa City, Iowa, and the Carman Study region near Winnipeg, Ontario, providing a valuable ground truth dataset for a critical agricultural region. The results of this experiment have since been providing datasets for the revision of algorithms for monitoring soil moisture in row crop domains, such as the central and northern plains of the United States. This will ultimately improve the understanding of soil moisture, climate and weather dynamics in a drought-prone region of significant interest to the USDA action agencies and to U.S. producers.

A risk assessment tool widely useful for action agencies. Action agencies such as USDA-NRCS, USDA-Forest Service (FS), Bureau of Land Management (BLM), and state agencies need a useful

tool for evaluating the risk of excessive runoff and soil erosion on rangeland sites relative to desired or optimal rangeland conditions and after fires. ARS scientists in Tucson, Arizona, formally documented the capability of the Rangeland Hydrology and Erosion Model (RHEM) Risk Assessment Tool RHEM V2.3 for simulating flow and soil erosion on a small watershed in Arizona and on 124 sites in Arizona and New Mexico. This model provides a widely tested tool that will have significant impact on understanding, assessing, and managing western rangelands in the United States. In addition, this tool will greatly facilitate the development of Ecological Site Descriptions, which are formal documents that are currently being developed in a large and active program across the United States by NRCS, FS, and BLM to describe the hydrologic and vegetation functions of land resources, particularly for grazing lands.

New web service increases public and private usefulness of popular runoff prediction tool. The desktop computer application WinTR-20 remains a widely-used modeling tool for assessing runoff from fields and small watersheds, and its use through NRCS is expected to continue for the foreseeable future. A web-service version of TR-20, the computational engine of WinTR-20, was developed and implemented to facilitate timely updates and revisions to enable online deployment through a partnership of ARS researchers at Fort Collins, Colorado, NRCS, and Colorado State University. By implementing TR-20 as a web service, this model is more accessible and can be reused and repurposed for other current and future applications. It is accessible by the general public using both direct access and through a website that provides a common, simple application of the web service.

Use of weather forecasting improves nutrient management planning with the Phosphorus Index. Phosphorus is at the core of modern agricultural nutrient management, representing both a valuable resource with finite global reserves and an environmental concern, as exemplified by its role in degrading the water quality of the Chesapeake Bay, Lake Erie and the Gulf of Mexico. ARS scientists at University Park, Pennsylvania, in collaboration with ARS scientists at other locations and university partners across the country, led efforts to evaluate and update nutrient management planning that uses the Phosphorus Index, a tool that has been adopted by 47 U.S. states. This group developed state-of-the-art tools that harness weather forecasting for use in nutrient management decision models for verifying that nutrient management planning tools support intended water quality outcomes.

A new scientific method for assessing big data aids increased understanding of environmental problems. Data-intensive research will increase understanding of environmental problems at large and small spatial extents and over time. Systems like the USDA Long-term Agroecosystem Research (LTAR) network provide data that is ecologically and hydrologically diverse to aid in exploring regional environmental dynamics. However, there is a need for an overall structure

and specific approach for processing these large, multi-location time series data sets. ARS scientists in Tucson, Arizona, developed a modified scientific method, where new ideas originate from individual scientists and the hypothesis, analysis, and conclusions are developed with the broader scientific community. The research results using the modified scientific method have been recognized for solid scientific contributions as measured by publication in high-impact journals, high citation records, and recent awards.

New photographic method aids understanding of cattle, wild horse and wildlife competition in riparian area grazing. Traditional methods to assess riparian grazing impacts typically focus on vegetation without distinguishing between wildlife and livestock use, and provide no information on actual animal presence or behavior. ARS scientists in Tucson, Arizona, and scientists at the University of Arizona, deployed an automated high resolution camera to capture images every 30 seconds for 38 days and created high resolution, zoomable videos of riparian area use by elk and cattle in Arizona. Elk exhibited the unique behavior of standing in and traveling within the stream channel while grazing, and grazed while lying down. The system is being used to quantify the impacts of wild horses at sites in Arizona where horses compete with cattle, wildlife, and humans for scarce riparian resources. This new photographic tool can document direct grazing impacts on public lands between cattle, large wild ungulates and wild horses at much lower cost than was previously possible across the western United States.