

FY 2019 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 2019. 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 research topics 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 2019, 133 full-time scientists working at 25 locations across the United States actively engaged in 32 ARS-led and 285 cooperative research projects in NP211. Base funding for the program was \$69M.

Personnel news for NP 211

New additions to the NP211 team in 2019 are:

- Two new scientists joined the Northwest Irrigation & Soils Research Lab in Kimberly, ID. **Dr. Chris Rogers** was formerly an Assistant Professor and Barley Agronomist with University of Idaho. Chris currently conducts research in carbon and nutrient uptake by crops. He will be involved with crop production studies that include dairy manure application and more aspirational crop rotations. **Dr. Kossi Nouwakpo** was formerly a Research Assistant Professor with University of Nevada, Reno, working closely with ARS's Great Basin Rangeland Research Unit in Reno. Kossi will be involved with a variety of water quality studies, especially CEAP, to determine effects of irrigation, tillage and crop effects on water balances and sediment and nutrient losses.
- The Hydrology and Remote Sensing Laboratory (HRSL) in Beltsville MD had two visiting scientists from the Ben-Gurion University of the Negev, Israel in 2019: **Dr. Arnon Karnieli**

conducted collaborative research on the application of remote sensing for monitoring vineyard phenology and development and plant emergence of croplands at BARC and Lower Chesapeake Bay LTAR. **Dr. Nurit Agam** conducted collaborative research on evapotranspiration and surface energy balance measurement and modeling of vineyards as part of the GRAPEX project.

- The Water Quality and Ecology Research Unit in Oxford MS hosted visiting scientist **Dr. Claudio Spadotto** from Empresa Brasileira de Pesquisa Agropecuária – Embrapa, Campinas, Brazil. He worked on developing improved USDA AnnAGNPS watershed modeling technology that addresses the sorption of ionizable pesticides in soils and the evaluation of the impact of pesticide agricultural practices on the environment.
- HRSL in Beltsville MD also welcomed two postdoctoral research associates in 2019: **Dr. Jie Xue** joined HRSL in January 2019 and is developing methods to combine imagery from multiple satellite platforms to provide daily sub-field-scale crop water use information to growers and to the water resources management community. **Dr. Ling Du:** is working on Deep Learning approaches using lidar and optical data for characterizing agricultural landscapes.
- The Northwest Watershed Research Laboratory in Boise ID hired **Dr. Andrew Hedrick** as a postdoctoral research associate. His work directly supports the Boise Snow Water Supply Forecasting Team’s research and modeling program.
- The Southwest Watershed Research Center in Tucson AZ hosted two postdoctoral research associates in 2019: **Dr. Andrew Fullhart** got his Ph.D. from University of Wyoming. Andrew’s goal is to improve estimates of precipitation intensity (from daily totals) for erosion predictions nationally and internationally. **Dr. John Knowles** joined SWRC after a 2 year Post-doc position at the University of Arizona. John is funded by an agreement with Lawrence Berkeley Lab (DOE) to work on flux tower synthesis for Ameriflux.
- The Water Quality and Ecology Research Unit in Oxford MS had two ORISE postdoctoral research associates in 2019: **Dr. Madhav Dhakal** received his Ph.D. at Texas Tech University. He is working on soil nutrient leaching in the Mississippi Delta, as well as tillage and cover crop effects on soil health and water quality. **Dr. Amanda Nelson** came from the ARS Grazinglands Research Laboratory in El Reno, Oklahoma. She is working on tailwater recovery systems with multiple field studies assessing runoff water quantity and quality in the Delta.
- The Water Quality and Ecology Research Unit in Oxford MS also hosted visiting PhD student **Mr. Iker Hernández-García** from University of Navarre, Pamplona, Spain. He worked on the evaluation of nitrogen loading using the USDA AnnAGNPS watershed modeling technology and two monitored watersheds in Navarre (Spain) that resulted in a better understanding of nitrogen transport and loading processes that will lead to model improvements.

The following scientists left the ranks of NP211 in 2019:

- **Dr. Don Meyer**, former research leader at the National Sedimentation Laboratory, Oxford, MS passed away July 29, 2019. He was internationally renowned for his erosion research program and had a long and rich career at ARS.
- **Dr. Phil Bauer** of the Coastal Plain Soil, Water and Plant Conservation Research Unit in Florence, SC retired in 2019.

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 2019:

- A team of ARS scientists and engineers from Bushland, TX; Beltsville, MD; Florence, SC; Portageville, MO; and Stoneville, MS received the 2019 Excellence in Technology Transfer Award from the Federal Laboratory Consortium Mid-Continent Region. Team co-lead **Dr. Susan O'Shaughnessy** received the award for the team at the Federal Laboratory Consortium Far West /Mid-Continent Regional Meeting, in Livermore, CA. The award recognized the success of a 9-year effort to bring several intertwined technologies to commercial availability and the integration of these technologies into a patented Irrigation Scheduling Supervisory Control And Data Acquisition (ISSCADA) system that was licensed in 2018 by a major center pivot irrigation system manufacturer for use as the decision support system (DSS) for its variable rate irrigation products. The ISSCADA system is the first DSS able to automatically acquire the necessary field measurements and write variable rate irrigation prescription maps and deliver the map for use by the farmer with the click of an icon. ISSCADA works as well with center pivot systems not equipped with variable rate hardware. ISSCADA subsystems developed by the team include a wireless sensor network of non-contact infrared thermometers (IRTs) to assess spatially varying crop leaf temperature and water stress; a suite of low-power, accurate soil water sensors to assess soil water availability; and a wireless node and gateway system for gathering soil water data from field locations and transmitting it through the cellular telephone network to the Internet Cloud where it can be accessed by ISSCADA. All three subsystems are commercially available and enjoying vigorous sales of made-in-the-USA products in the U.S. and internationally. Other scientists sharing in this award were **Dr. Ruixiu Sui** of the Sustainable Water Management Research Unit in Stoneville MS; **Dr. Kenneth Stone** of the Coastal Plain Soil, Water and Plant Conservation Research Unit in Florence, SC; **Dr. Steve Evett** and **Dr. Paul Colaizzi** of the Conservation and Production Research Laboratory, Bushland TX; **Dr. Earl Vories** of the Cropping Systems and Water Quality Research Unit, Columbia MO; and **Dr. Harry**

Schomberg of the Sustainable Agricultural Systems Laboratory, and Sustainable Water Management Research Unit, Beltsville MD.

- **Dr. Newell Kitchen** of the Cropping Systems and Water Quality Research in Columbia MO was selected by the American Society of Agronomy (ASA) as the recipient of the 2019 Werner L. Nelson Diagnosis of Yield-Limiting Factors Award. The focus of this award is on leadership and accomplishments in development and/or implementation of workshops, checklists, visual aids, or techniques for diagnosing crop yield-limiting factors that result in the application of site-specific measures. The award is provided through the Agronomic Science Foundation by the Werner L. Nelson Fund and administered through ASA.
- **Dr. Ken Sudduth** of the Cropping Systems and Water Quality Research in Columbia MO was awarded the American Society of Agricultural and Biological Engineers John Deere Gold Medal for “Distinguished Achievement in the Application of Science and Art to the Soil,” and ARS Midwest Area Senior Research Scientist of the Year in 2019.
- **Dr. Andrew Hedrick** and his team at Northwest Watershed Research Laboratory in Boise ID team received a prestigious Editors’ Choice Award for their paper entitled “Direct insertion of NASA Airborne Snow Observatory-derived snow depth time series into the iSnobal energy balance snow model,” from Water Resources Research journal.
- **Dr. Kelly Thorpe** of the Water Management & Conservation Research Unit in Maricopa AZ received the Laj Ahuja Ag Systems Modeling Award from the Soil Science Society of America, and the ASABE Superior Paper Award from the American Society of Agricultural and Biological Engineers in 2019.
- **Dr. Andy French** of the Water Management & Conservation Research Unit in Maricopa AZ received an ARS Innovation Fund award for developing an Irrigation Phone App with Satellite Data.
- **Dr. Eduardo Bautista** of the Water Management & Conservation Research Unit in Maricopa AZ was named an Outstanding Reviewer by the Journal of Irrigation Drainage Engineering and received Editors’ Choice and Superior Paper Awards from the Journal of Irrigation Drainage Engineering.
- **Dr. Scott Bradford** of the U.S. Salinity Laboratory in Riverside CA was awarded the 2019 Don & Betty Kirkham Soil Physics Award, a prestigious award administered by the Soil Science Society of America which recognizes mid-career scientists who have made outstanding contributions in the areas of soil physics.
- **Dr. Leonard Lane**, retired, from the Southwest Watershed Research Center in Tucson, AZ was given the 2019 Hugh Hammond Bennett Award from the Soil and Water Conservation Society.
- **Dr. Sherry Hunt** of the Hydraulic Engineering Research Unit in Stillwater, OK received three awards in 2019: she was elected a Fellow of the American Society of Agricultural and Biological Engineering (ASABE), ASABE’s highest honor recognizing members of unusual

professional distinction, with outstanding and extraordinary qualifications and experience in, or related to, the field of agricultural, food, or biological systems engineering; received ASABE's G. B. Gunlogson Countryside Engineering Award in recognition for embankment dam engineering contributions that have promoted the development and flood protection of country sides worldwide; and received the Association of State Dam Safety Officials (ASDSO) Terry L. Hampton Medal, in recognition of significant leadership and research in hydraulic structure design for aging dams and her development of dam safety engineering tools, training, and guidance documents.

In 2019, a number of factors demonstrated the quality and impact of NP 211 research:

- Publication of 295 peer-reviewed journal articles;
- 1 new patent application and 2 new material transfer agreements; and
- 185 students and postdoctoral research associates training with ARS

In 2019, 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 FY2019

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 2019 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

Alternate cropping systems can conserve groundwater. Decreased irrigation well capacities due to declining groundwater levels in the Ogallala Aquifer will eventually limit the production of corn in the northern High Plains of Texas, which currently is one of the region's most profitable crops. Alternatively, less water-intensive crops may conserve groundwater while allowing producers to remain profitable. To solve this challenge, scientists from ARS in Bushland Texas, and the Texas A&M AgriLife Research and Extension Service used the Soil and Water Assessment Tool, a hydrologic model, and equipped it with a newly developed irrigation program to simulate water use associated with soybean, sunflower, and grain sorghum. Results indicated that irrigation amounts were reduced by 19, 21, and 32 percent, respectively, compared with amounts of water used to grow corn. Substituting grain sorghum for corn at 70 percent of its optimum irrigation amount resulted in greater income per acre, whereas substituting sunflowers for corn at 80 percent of the optimum irrigation amount for corn had little effect on income per acre. These results are of interest to farmers, crop consultants, and regional water policymakers who need to identify crops other than corn that can be grown where groundwater availability is limited.

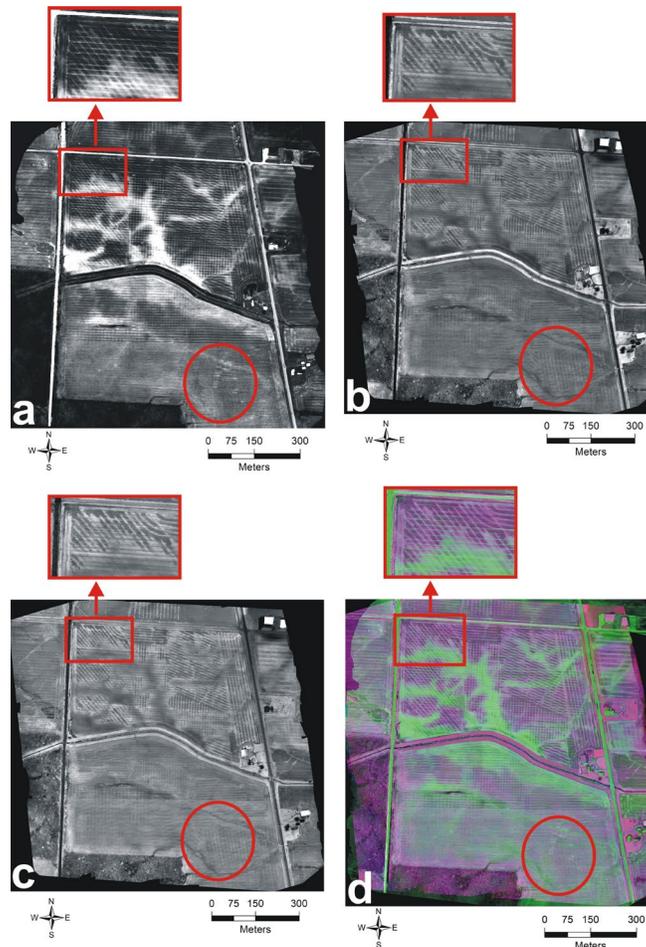


Sustainable cotton production. While molecular biologists have developed plants with traits such as resistance to herbicides or insect damage, no single gene has been identified that is associated with drought tolerance. Maintaining yield under drought stress is important because precipitation is seldom optimal in the southwestern U.S. and irrigation water resources are being depleted. Scientists from ARS in Lubbock, Texas, Texas Tech University, Tohoku University (Japan), and the Volcani Center (Israel) inserted a gene from tomatoes into cotton plants. Cotton plants altered with the tomato gene continued to use sunlight to function under conditions where unaltered plants had stopped functioning. Over the course of a preliminary small-scale pilot study, cotton yield was increased by 80%. These results suggested that this approach could result in traits to sustain or even improve cotton yield under mild-drought conditions typical of the southwestern U.S.

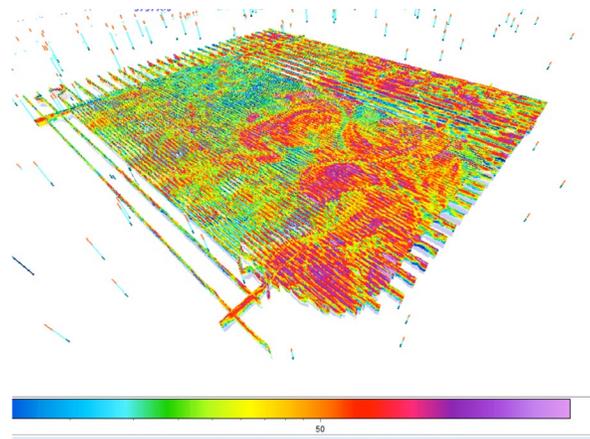
Effective and efficient mapping of agricultural drain pipes. In order to modify or repair subsurface drainage systems, or to evaluate environmental impacts of drainage practices, an effective, efficient, and non-destructive approach is needed for locating pre-existing drainage pipes. Ground-penetrating radar integrated with Real-Time Kinematic Global Navigation Satellite System (RTK/GNSS) was tested for mapping subsurface drainage systems in three agricultural fields; two in Beltsville, Maryland and one in Pataskala, Ohio. The GPR-RTK/GNSS set-up used in this study delineated a complex rectangular drainage pipe system at one of the Beltsville Maryland sites, a herringbone drain line pattern at the second Beltsville, Maryland, site, and random drain lines at the Pataskala, Ohio site. When integrated with RTK/GNSS, spiral or serpentine GPR transects (or spiral/serpentine segments of a GPR transects) were found to provide valuable insight on drain line directional trends. Consequently, given suitable field conditions, GPR integrated with RTK/GNSS can be adopted by farmers, drainage contractors, and watershed environmental coordinators to identify and map existing subsurface drainage systems within agricultural settings, providing considerable time savings for identifying and repairing pipe and providing additional information for water quality assessments.

Agricultural drainage pipes can be mapped using a combination of thermal infrared and multispectral imagery obtained with a drone. In order to modify or repair subsurface drainage systems, or to evaluate environmental impacts of drainage practices, an effective, efficient, and non-destructive approach is needed for locating pre-existing drainage pipes. Thermal infrared and multispectral imagery obtained with a drone were tested for mapping drain lines in an agricultural field located near Harlan, Indiana. The combined thermal infrared and multispectral imagery depicted some random linear features potentially associated with drain line locations. Some of these linear features showed up better in the thermal infrared imagery, while others were more well defined in the multispectral imagery. Ground penetrating radar confirmed that these linear features depicted in the drone imagery did represent drain lines. Although more

research is needed, ARS researchers from Columbus, Ohio, in collaboration with USGS researchers showed that combined thermal infrared and multispectral imagery obtained with drone can be a useful tool for farmers, drainage contractors, and watershed environmental coordinators needing information on existing subsurface drainage systems within agricultural settings.

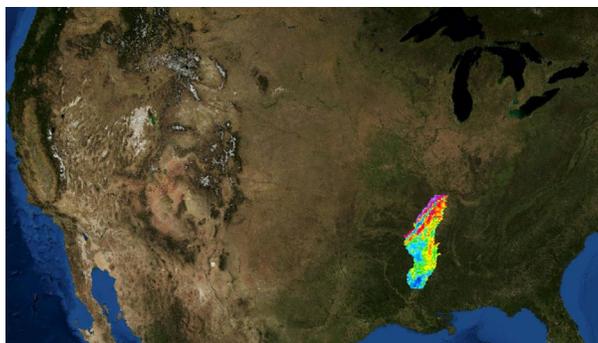


Hardin County, Ohio UAV site survey results; (a) TIR, (b) near infrared (NIR), (c) red edge, and (d) color composite of TIR, NIR, and red edge.



High resolution imaging of the aquifer in a 30 km by 30 km area will support an innovative USDA ARS pilot project for exploring the feasibility of managed aquifer recharge in the Mississippi River Valley alluvial aquifer to support irrigated agriculture.

Complexity of Mississippi River Valley Alluvial Aquifer (MRVA) revealed. The MRVA is one of the most productive agricultural aquifers in the United States, supplying irrigation for 8 million acres of arable land, which results in approximately \$9 billion in direct revenues annually for crops. Reliance on groundwater for irrigation has resulted in alarming declines in groundwater levels across the region. Using an airborne geophysical mapping survey, ARS researchers in Oxford, Mississippi, in collaboration with the U.S. Geological Survey have updated the basic understanding of the aquifer and its recharge sources. This mapping effort provided an unprecedented three-dimensional view of the entire aquifer structure thereby revealing deep structure such as paleochannels and preferential flow paths. This survey will provide a long-term foundation for hydrologic and geologic research in the region to support sustainable water resources.



The airborne mapping of the Mississippi River Valley alluvial aquifer is the largest airborne survey ever conducted in the continental United States in support of water resources management.

Variable rate irrigation (VRI) technology. Due to overuse of ground water from the Mississippi Alluvial Aquifer for irrigation, ongoing depletion of the aquifer has become a threat to agriculture sustainability in the Lower Mississippi River Basin. It is necessary to use advanced irrigation technologies to save water in crop production. Soil properties and plant characteristics can vary considerably within a single field, resulting in variability of water need for plant to reach its yield potential. ARS researchers in Stoneville, Mississippi, developed VRI technology to site-specifically apply irrigation water within a field to account for the temporal and spatial variability in soil and plant characteristics. VRI prescriptions were created based on soil electrical conductivity and irrigation was scheduled according to the sensor-measured soil moisture content. Desired amount of water was applied site-specifically according to the VRI prescriptions. The field tests showed that use of this VRI technology saved 25% of irrigation water.



Variable rate irrigation application

Erosion, Sedimentation, and Water Quality Protection

Selected Accomplishments

Stepped spillway design criteria adopted by Federal agencies and architectural and engineering consulting firms. Roller-compacted concrete (RCC) stepped spillways provide embankment overtopping protection and increased capacity for aging embankment dams. An ARS researcher in Stillwater, Oklahoma, developed a systematic, step-by-step RCC spillway design guideline to rehabilitate aging embankment dams. The Natural Resources Conservation Service (NRCS) is incorporating the criteria into its National Engineering Handbook and expects it to be implemented on approximately 1,200 aging USDA-assisted dams. NRCS experts say the criteria will provide construction cost savings ranging from \$600 million to \$1.2 billion compared with other embankment overtopping protection systems. The U.S. Army Corps of Engineers is also integrating the criteria into its revised spillway design technical manual (EM 1110-2-1603). In addition, this research has become an industry standard among architectural and engineering consulting firms across the United States for upgrading aging dams. This technology is assisting dam safety engineers in preserving the \$2.3 billion in annual benefits (i.e., flood control, rural and municipal water supplies, irrigation for agricultural production, recreation, and wildlife habitat among others) provided by USDA-assisted dams.



Stepped spillway design.

Improving water quality with field-edge nitrate removal. Saturated riparian buffers are a promising new development in efforts to remove nitrate from farm field drainage; however, only limited data are available on the effectiveness of the practice. By monitoring six sites for 2 to 9 years, ARS researchers in Ames, Iowa, in cooperation with researchers at Iowa State University, have shown that saturated riparian buffers can remove 40 to 90 percent of nitrate leaving a farmer's field before it enters a stream or river. The scientists also demonstrated that nitrate removal occurs primarily from denitrification (the conversion of nitrate to nitrogen gas) and that this conversion does not increase the generation of nitrous oxide, a powerful

greenhouse gas. This research has led the Natural Resources Conservation Service to develop a new conservation practice standard for implementation on Midwest farms.



New bank stability assessment technology helps protect rivers and streams. The erosion resistance of streambank soils can vary significantly in space and time. Current bank erosion prediction technology does not account for this variability, which makes it difficult to select appropriate soil erosion-resistance values when assessing bank erosion. ARS researchers in Oxford, Mississippi, developed a new way, using stochastic analysis, to estimate expected bank erosion by incorporating parameters such as soil erodibility and shear strength into ARS's widely used Bank Stability and Toe Erosion Model (BSTEM). The new BSTEM version is able to determine the probability that bank retreat magnitudes may be exceeded. This is crucial information when critical infrastructure is located near rivers and streams. As part of the \$1.6 billion American River Common Features project, the new technology is currently being used by the Sacramento District of the U.S. Army Corps of Engineers to prioritize bank protection measures to prevent levee failure around the City of Sacramento, California.

Design and demonstration of the construction of a phosphorus removal structure.

Phosphorus (P) removal structures are intended for reducing phosphorus pollution that causes eutrophication of surface water bodies such as Lake Erie. Reducing eutrophication to surface waters is important to the economy, ecosystem, drinking water treatment, and recreational use. While phosphorus removal structures are useful in helping to filter dissolved phosphorus before it reaches a body of water, there is a need to disseminate this new conservation practice to farmers, non-profits, state agencies, and to help train potential service-providers. ARS scientists at West Lafayette, Indiana, designed a large underground tile drain P filter using 60 tons of slag, on a large swine farm near Holland, Michigan. This was the largest tile drain filter

ever constructed using tanks. A journalist from the American Society of Agronomy filmed and documented the process, for future use in several training modules. At least twenty people came to see the construction of the unit, representing non-profit organizations such as Friends of Lake Macketawa, the Outdoor Discovery Center, American Society of Agronomy, and the American Society of Agricultural and Biological Engineers, as well as NRCS engineers and conservationists. While some participants released several pictures to social media, several groups contacted ARS for more information, including Drainage Contractor Magazine. This effort not only trained people interested in how to construct P removal structures, but also resulted in the dissemination of the technology to an unknown number of people. Increased adoption of this practice, and training of people for providing the service, will decrease dissolved phosphorus loading to surface water bodies and improve water quality.



Conservation practices for the Eastern Corn Belt. Nutrient loss, particularly phosphorus, from crop production agriculture has been linked to harmful and nuisance algal blooms in Lake Erie and other freshwater systems in Ohio. The binational agreement between the U.S. and Canada calls for a 40% reduction in phosphorus delivery. Using a paired edge-of-field approach, ARS researchers in Columbus, Ohio, in collaboration with Lake Erie stakeholders and partners, quantified the surface and subsurface (tile) water quality contributions of various crop production and conservation management practices. The combination of legacy phosphorus and discharge significantly contribute to agricultural losses and highlight the need for regionally based conservation management. Promotion and adoption of 4R practices (source, rate, time, and place) and drainage water management could potentially reduce agriculture’s environmental footprint in the Midwest United States. Cover crops have a significant impact on nitrogen losses but do not have an equal impact on phosphorus. These findings have been shared and delivered to Lake Erie stakeholders and partners (e.g., NRCS, The Nature Conservancy, Lake Erie Foundation) and are being promoted to producers to help address eutrophication of Lake Erie. Adoption of these practices would reduce agriculture’s

environmental footprint and make progress toward the 40% phosphorus reduction goals set for the Western Lake Erie Basin.



Enhancing and Documenting the Benefits of Conservation Practices

Selected Accomplishments

Alternative livestock forages increase soil health and drought tolerance. Scientists from Texas Tech University and ARS in Lubbock, Texas previously found improvements in soil health indicators (e.g., microbial community, organic matter, and enzyme activities of nutrient cycling) with the introduction of Old-World bluestem (OWB) grass for livestock-cotton production in the Southern High Plains. The system also reduced tillage and irrigation 36% compared to monoculture cotton. Soil health was further compared under other forages more drought tolerant than OWB, which included OWB-alfalfa, alfalfa, and native mixed-grass pastures. The OWB-alfalfa system offered suppression of pestiferous ants, desirable cattle productivity when grazed, eliminated fertilizer requirements due to N fixation and enhanced soil health indicators, i.e., greatest fungal and bacterial populations and their enzyme activities. The forage system with alfalfa can provide a desirable forage for producers in a semi-arid region with a declining irrigation-water supply.

Impact of water irrigation practices on rice field CH₄ emissions. Approximately 11% of the global anthropogenic methane emissions are currently attributed to rice cultivation. ARS scientists in Jonesboro, Arkansas evaluated the impact of water irrigation practices on rice field CH₄ emissions in Arkansas, where more than half of U.S. rice is produced. Typical rice irrigation uses continuous flooding (CF) during the majority of the production season. While conserving water, the Alternate Wetting and Drying (AWD) irrigation practice can also reduce CH₄ emissions through the deliberate, periodic introduction of non-flooded conditions. Continuous measurements of methane flux indicated a 79% reduction in season-long emissions from the AWD field relative to the CF field. The seasonal cumulative carbon losses by CH₄ emission were 30.3 and 141.9 kg CH₄-C/ha for the AWD and CF fields, respectively. Considering differences in field conditions and soils, the AWD practice is attributable to a 36-51% reduction in seasonal emissions. The substantial decrease in CH₄ emissions by AWD offers strong evidence for the efficacy of AWD in reducing methane emissions in Arkansas rice production. The AWD practice is under consideration for carbon offsets trading and this new market could encourage greater reductions in methane emissions on a larger scale.



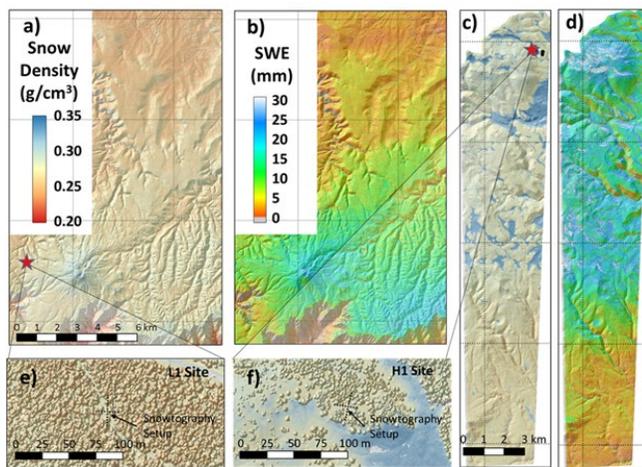
Mulch and gypsum help reduce nutrient export into rivers. Runoff containing excess nitrogen and phosphorus fertilizer from agricultural fields can be transported into water bodies and cause algal blooms and dead zones that impact fisheries and tourism. Denitrification is a natural process that transforms nitrogen, like that from fertilizer, into an unreactive gas. ARS researchers at Oxford, Mississippi, examined the ability of additions such as hardwood mulch and mulch mixed with gypsum to enhance denitrification in sediment cores taken from edge-of-field systems. Mulch and mulch-gypsum amendments were able to remove 65-69% of the nitrogen load in the system. When gypsum was included with the mulch, release of phosphorus from the system significantly decreased. Adding organic carbon sources to the sediment cores significantly increased denitrification rates. By adding inexpensive organic sources, such as hardwood mulch, to edge-of-field systems such as ditches, farmers can reduce the impact of nitrogen pollution while maintaining agricultural production.



Watershed Management to Improve Ecosystem Services in Agricultural Landscapes

Selected Accomplishments

Improved snow water equivalent maps. Knowing the quantity of water in snowpack (the snow water equivalent or SWE), is critical for water supply forecasts and management of rivers and streams for water delivery and hydropower, as most western surface water originates from mountain snowmelt. Scientists from the University of Arizona and ARS in Tucson, Arizona, developed a new method to estimate SWE by combining aerial remote sensing maps of snow depth with snow density maps generated through machine learning of hundreds of field measurements of snow density. The study found that snow density can vary by as much 75%, highlighting the importance of spatial variability when estimating SWE. In addition, spatially variable maps of snow density can impact watershed-scale SWE estimation up to 20% as compared to using snow density measurements from commonly used snow monitoring stations. This new method will improve SWE estimates for water supply monitoring, evaluating snow models, and understanding how changing mountain forests might impact SWE.



Improving weather forecasting. The United Kingdom's Meteorological (Met) Office makes routine regional and global weather forecasts that are commonly used in US forecasting. But the computer models have substantial errors in surface temperature, particularly over arid regions, which causes errors in their weather forecasts. To investigate these errors and improve the weather model forecasts, ARS researchers in Tucson Arizona, and the Met Office,

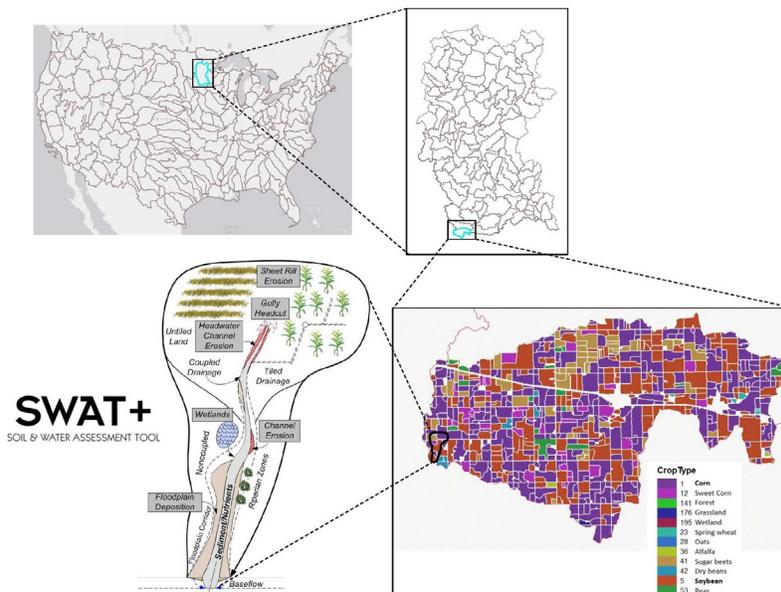
conducted an experimental campaign using ground, airborne and satellite measurements at the Walnut Gulch Experimental Watershed. The model temperatures were confirmed to be too cold with respect to the ground-based temperatures, and this bias was related to the model bare soil fractions that are too low and not adequately simulating the patchy, shrub-covered landscapes found in many arid lands. Improving the model representation of vegetation and soil demonstrated better simulation of the surface temperatures and moistures, which will improve weather forecasts.



Assessment of future water availability for agriculture. California has high variability in water availability, and the potential for extended future droughts with changes in climate is widely perceived to be a substantial risk. However, models have high uncertainty with respect to future precipitation climatology, with some models showing substantially drier future climates while others show increasing precipitation. An ARS scientist in Riverside, California, worked with collaborators to test climate models based on their ability to reproduce El Niño, which has a major impact on the likelihood of a wet winter in California and high agricultural water availability. Models that did a better job of simulating El Niño showed a significantly lower risk of drought. However, precipitation was increasingly concentrated in core winter months (December, January, and February) and in major rain storms that can produce floods that flow directly to the ocean. These results suggest that added agricultural water storage capacity will be needed to effectively mitigate against warmer and drier summer periods and to maintain the same relative agricultural water availability.

Official release of SWAT+ to the public. The Soil and Water Assessment Tool plus (SWAT+) is a revised modular version of SWAT with improved flexibility in watershed configuration, a new

relational input file structure, and additional capabilities in water allocation and reservoir operation. The SWAT+ model was officially released at the International SWAT Conference in Vienna in July 2019. The first SWAT+ workshop was conducted to train participants in the use of the QGIS (Quantum Geographic Information System) interface and associated input file editor. Model code and example data sets were made available at a website used for archiving and version control. In addition, a user manual is now available at the [SWAT website](https://swat.tamu.edu/software/plus/) (<https://swat.tamu.edu/software/plus/>). SWAT is one of the most widely used hydrologic and water quality models in the U.S. and internationally. With the development of SWAT+, researchers can more accurately predict the impact of human activities on the environment, especially at the local level. SWAT+ is currently being used as the modeling engine behind the National Agroecosystem Model (NAM), a nationwide model used for research and policy development in the USDA. NAM and SWAT+ are integral components of the Conservation Effects Assessment (CEAP) project and ARS Long Term Agroecosystem Research (LTAR) project, both of which are designed to guide agricultural related policy at the federal level.



Development of field scale national modeling framework. The National Agroecosystems Model (NAM) is a framework of national datasets, processing software, and models developed to predict the impact of conservation policy, land use and management change, weather, and other human activities on pollutants which degrade the environment. NAM is a continuous effort, developed to address the evolving needs of Long-Term Agroecosystem Research (LTAR) and Conservation Effects Assessment Project (CEAP) and is improved in temporal and spatial scale as additional data and software become available. The current NAM model operates at the field scale for cultivated areas, containing 4.5 million fields within the contiguous U.S. Advances in remote sensing allow crop rotation and topographic characteristics of each

individual field to be included as a separate computational unit in SWAT+. County level NAM predictions combined with short term precipitation forecasts are currently being used in USDA-Natural Resource and Conservation Service's (NRCS) [Agricultural Operations Planning Tool](#) (AgOPT) to aid producers in scheduling the application of agrichemicals.

Chemical seed treatment of sugarcane billets. Sugarcane is not produced from seeds, but by planting vegetative stalks laid end to end in the soil. Tropical weather, saturated soils, and/or heavy winds can lodge sugarcane stalks, making them difficult to plant. Lodged cane can be cut into smaller pieces, called billets, using a machine harvester and then mechanically planted. However, conditions such as Louisiana's cool/wet winters and the rotting of stalks (caused by fungi) are detrimental to billet-planted sugarcane establishment. Therefore, cultural practices that improve the vitality of billet-planted cane are needed. ARS scientists at Houma, Louisiana, in collaboration with LSU AgCenter scientists, completed multi-year field trials at two locations in which they found that dip-treating billets with fungicides and insecticides prior to planting significantly improved crop yields by more than 40%, when compared to non-treated billets. Moreover, yields for chemically-treated billets were similar to or better (by as much as 14%) than traditionally-planted, non-treated stalks. The highest yielding treatment consisted of a fungicide-insecticide combination. The results offer growers an option to increase crop yields when climatic conditions are sub-optimal and non-conducive to planting whole stalks.

