

FY 2014 Annual Report
National Program 211 - Water Availability and Watershed Management

Introduction

The USDA-ARS National Program for Water Availability and Watershed Management (NP211) had a productive and dynamic year in 2014. 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.

The overarching goal of NP 211 is:

to effectively and safely manage water resources while protecting the environment and human and animal health.

There is no substitute for fresh water nor are there replacements for its essential role in maintaining human health, agriculture, industry, and ecosystem integrity. 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 its 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 water, aided flood management and soil conservation, and dramatically improved hygiene, health, and economic prosperity. The U.S. water resources and technologies were the envy of the world.

In the 21st century, the situation is much different for the U.S., and indeed for the world. Depleted ground water reserves, degraded water quality, and adverse climate conditions are reducing the amount of available freshwater. At the same time, allocations of our freshwater resources are shifting among different users and different needs (e.g., from agricultural to urban uses; from storing water supplies in reservoirs to maintaining in-stream flows to support healthy aquatic ecosystems; from industrial and energy production to recreation). Our shared freshwater supply has been reduced significantly and is becoming more variable, unreliable, and inadequate to meet the needs and demands of an expanding population.

Water-related science and technology have served our Nation well. We have built infrastructure that provides safe drinking water to our cities, irrigation water to grow a large portion of our Nation's food supply, water for industry, and the means to keep waterways navigable. Through improved waste treatment technologies, we have made great strides in improving water quality, and have protected and enhanced our waterways to provide habitat for aquatic organisms and recreational opportunities for the public.

Today, the agricultural and energy sectors are the two largest users of water in the U.S. Some of the water use is consumptive—water is lost through crop water use or evaporation from cooling. When fresh and saline water withdrawals for thermoelectric use are combined with those for hydropower, the energy sector has the largest water use. When only freshwater withdrawals are considered, agriculture is clearly the largest user of water and the least understood in terms of opportunities for conserving water supplies and improving water quality for drinking, swimming, and fishing.

In the 21st century, agriculture faces new challenges—the increasing demand for water by our cities, farms, and aquatic ecosystems; the increasing reliance on irrigated agriculture for crop and animal production and farm income; and changing water supplies due to groundwater depletion in some areas, climate variability, and global change. These challenges are not insurmountable. Science can provide the tools needed by water planners and managers to accurately predict the outcomes of proposed water management decisions, and new technologies can widen the range of options for future water management. The factual basis for decision-making includes an understanding of effectiveness, potential unintended consequences, and a plan for getting water users and agencies to adopt the most effective technologies. The Nation has the opportunity to use science and technology to build a strong economy and to improve human and ecological health.

The approach for this National Program is to address the highest priorities for agricultural water management (effective water management, erosion, sedimentation, and water quality protection, improving conservation effectiveness in agricultural watersheds, and improving watershed management and 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 water use efficiency; drainage water management and control; field scale processes controlling contaminant fate and transport; improving our understanding of the aggregate effects of conservation practices at the watershed scale; improving conservation practices to better protect water resources; maintaining the effectiveness of conservation practices under changing climate and land use; developing tools to improve hydrologic assessment and watershed management; and improving watershed management and ecosystem services through long-term observation and characterization of agricultural watersheds and landscapes. The overall goal is to provide solutions to problems in the utilization of the Nation's water resources.

This National Program is organized into four problem areas (components):

- Effective Water Management in Agriculture
- Erosion, Sedimentation, and Water Quality Protection
- Improving Conservation Effectiveness
- Improving Watershed Management and Ecosystem Services in Agricultural Landscapes

During FY 2014, 131 full-time scientists working at 25 locations across the U.S. actively engaged in more than 38 ARS-led and 292 cooperative research projects in NP211. ARS-led projects were approved through the ARS Office of Scientific Quality Review in 2011, making this the third year of implementation of these five-year projects. The gross fiscal year 2014 funding for NP211 was \$ 68 million.

New additions to the NP211 team in 2014 are:

- **Alisa Coffin** has joined the Southeast Watershed Research Laboratory in Tifton, GA as a post-doc. Dr. Coffin has a Ph.D. in Geography with a background in landscape ecology. Her expertise is remote sensing, GIS, spatial statistics and network analysis.
- **William Ford** has joined the Soil Drainage Research Unit in Columbus, OH. Bill had been serving as a grant funded post-doc focusing on APEX modeling for the Western Lake Erie Basin.
- **Katrina Gillette** has joined the National Laboratory for Agriculture and the Environment, Ames, IA, as a post-doc to work on incorporating nitrous oxide dynamics into crop models to evaluate against field observations.
- **Sean Gleason** has joined the Water Management Research Unit in Ft. Collins, CO. Sean specializes in whole plant responses to limited resources. He will conduct research on crop responses to water stress with the goal of developing management practices to maximize water productivity, and identify plant traits that can lead, through selection and breeding, to more drought tolerant crops.
- **Douglas Smith** joined the NP211 team at the Grassland, Soil and Water Research Laboratory in Temple, TX. Doug came from USDA-ARS National Soil Erosion Research Laboratory in West Lafayette, IN and is a soil scientist who conducts research on landscape-scale fate and transport of nutrients and other contaminants.
- **John Tatarko**, Soil Scientist, has relocated from the Engineering and Wind Erosion Research Unit in Manhattan, KS, to the Agricultural Systems Research Unit in Ft. Collins, CO. He will be working on research on management effects on wind erosion.
- **Mark Williams** joined the NP211 team at the Soil Drainage Research Unit in Columbus, OH. Mark had been serving as a headquarters funded post-doc focusing on nutrient movement to subsurface drains through macropores.
- **Huihui Zhang**, a remote sensing specialist, has joined the Water Management Research Unit, Ft. Collins, CO. She will lead the Unit's efforts to optimize crop irrigation in water limited areas through the use of remotely sensed information from ground, UAV, manned aerial, and satellite platforms.

The following scientists retired from the ranks in NP211:

- **Walter Bausch** and **Dale Shaner** from the Water Management Research Unit, Ft. Collins, CO.
- **Tim Gish**, from the Hydrology and Remote Sensing Laboratory in Beltsville, MD.
- **Patrick Hunt**, from the Coastal Plains Soil, Water, and Plant Research Center, Florence, SC.
- **Bill Koskinen**, from the Soil & Water Management Unit in St. Paul, MN.

- **Jeanne Schneider**, from the Grazinglands Research Laboratory, El Reno, OK. Jeanne's work has focused on climate adaptation and risk-based decision-making. In the last year of her career, she served as the USDA Southern Plains Climate Hub Lead.
- **Theodor 'Fedye' Strelkoff**, from the Water Management and Conservation Research Unit in Maricopa, AZ.

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 2014:

- **James C. Ascough II** of the Agricultural Systems Research Unit in Ft. Collins, CO was awarded the Biennial Medal at the International Environmental Modeling & Software Society (iEMSs) 2014 Biennial Conference. The iEMSs Biennial Medal is awarded for "Exceptional research contributions to environmental modeling and software, and for promoting the aims of the Society."
- **Ray Bryant** of the Pasture Systems & Watershed Management Research in University Park, PA, **Martin Locke** of the Water Quality and Ecology Research Unit, Oxford, MS, and **Rodney Venterea** of the Soil & Water Management Unit in St. Paul, MN, were all named fellows of the Soil Science Society of America.
- **Peter Kleinman** of the Pasture Systems & Watershed Management Research in University Park, PA was named a Fellow of the Soil and Water Conservation Society.
- **Daren Harmel** and **Douglas Smith**, Temple, TX, received the Best Research Paper award for Impact and Quality (Honorable Mention) from the Journal of Soil and Water Conservation.
- **Jerry Hatfield**, Director of the National Laboratory for Agriculture and the Environment, Ames, IA, was inducted into the ARS Science Hall of Fame and awarded the Outstanding Research Paper for Quality and Impact by the Soil and Water Conservation Society.
- **Jean Steiner**, Grazinglands Research Laboratory, El Reno, OK, is currently serving as the President of the American Society of Agronomy.

In 2014, a number of factors demonstrated the quality and impact of NP 211 research:

- Publication of 249 refereed journal articles;
- A new patent application and the submission of three new invention disclosures;
- Four current cooperative research and development agreements with stakeholders
- The development of fifty–six new scientific technologies; and
- The development or administration of 25 web sites for academia or stakeholders.

In 2014 NP 211 scientists collaborated with scientists in Argentina, Australia, Austria, The Bahamas, Belgium, Brazil, Canada, China, Czech Republic, Ethiopia, France, Germany, India, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Mexico, Mongolia, Namibia, Nepal, Netherlands, New Zealand, Nigeria, Pakistan, Palestine, Panama, Philippines, Portugal, Saudi Arabia, Senegal, South Africa, South Korea, Spain, Switzerland, Taiwan, Tanzania, Thailand, Tunisia, Turkey, United Kingdom Uruguay, and Uzbekistan.

NP 211 Accomplishments for FY2014

This section summarizes significant and high impact research results that address specific components of the FY 2011 – 2015 action plan for NP 211. Each section summarizes accomplishments of individual research projects in NP 211. Many of the programs summarized for FY 2014 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, which enhances the impact of ARS research programs.

EFFECTIVE WATER MANAGEMENT IN AGRICULTURE

Human civilization learned millennia ago that supplying adequate food and fiber in many regions requires artificial manipulation of the natural hydrology through irrigation and drainage. In the U.S., irrigated agriculture produces 49% of crop market value on 18% of cropped lands. Irrigation is essential to the most highly productive, intensely managed, and internationally competitive sectors of our agricultural economy, which play a key role in meeting growing global food, fiber, and energy needs. Equally important to production agriculture are surface and subsurface drainage. On approximately 120 million acres throughout the nation, removing excess water has resulted in reliable crop production. Yet agriculture is subject to growing competition for water resources, and dealing with adverse environmental effects and inevitable reductions in water resources available for irrigated agriculture in some areas necessitates the development of improved irrigation and drainage systems.

Selected Accomplishments

A new model, iSnobal, for managing snowmelt in the western U.S. In the face of climate change, water supplies from western mountainous watersheds are in extremely high demand for agricultural production, clean electricity, and domestic uses. Optimizing water supply management requires traditional methods of stream flow forecasting based on simple empirical relationships between snowpack measurements and stream flow be improved. ARS scientists in Boise, Idaho, developed a new more sophisticated model, iSnobal, that goes beyond these simple empirical relationships. iSnobal has not been used for management purposes however, because of its high computational demands, and because simulating snow accumulation and melt patterns over large areas requires significant expertise. Over the past year, ARS scientists successfully integrated the iSnobal model into the U.S. Bureau of Reclamation forecasting procedures for the 2500 square mile Boise River Basin in Idaho. As a result, they are now providing weekly updates of snow cover density and state over a large region of the southern Sierra Nevada Mountains for the National Aeronautics and Space Administration (NASA) Alpine Snow Observatory program. This represents a major change in the commitment of western water managers towards more sophisticated process-based modeling for their future river forecasting programs.

Flerchinger, G.N., Lehrsch, G.A., McCool, D.K. 2013. Freezing and thawing processes. Online Reference Database Earth Systems and Environmental Sciences. DOI: 10.1016/B978-0-12-409548-9.05173-3.

Kongoli, C., Kustas, W.P., Anderson, M.C., Norman, J.M., Alfieri, J.G., Flerchinger, G.N., Marks, D.G.

2014. Evaluation of a two-source snow-vegetation energy balance model for estimating surface energy fluxes in a rangeland ecosystem. *Journal of Hydrometeorology* 15(1):143-158.

Kormos, P., Marks, D.G., Williams, C.J., Marshall, H., Aishlin, P., Chandler, D., McNamara, J.P. 2014. Soil, snow, weather, and sub-surface storage data from a mountain catchment in the rain-snow transition zone. *Electronic Publication* 6:165-173.

Newman, A., Clark, M., Winstral, A.H., Marks, D.G., Seyfried, M.S. 2014. The use of similarity concepts to represent sub-grid variability in hydrologic and land-surface models: case study in a snowmelt dominated watershed. *Journal of Hydrometeorology*. DOI: 10.1175/JHM-D-13-038.1.

Reba, M.L., Marks, D.G., Link, T., Pomeroy, J., Winstral, A.H. 2014. Sensitivity of model parameterizations for simulated latent heat flux at the snow surface for complex mountain sites. *Hydrological Processes* 28:868-881.

Winstral, A.H., Marks, D.G. 2014. Long-term snow distribution observations in a mountain catchment: assessing variability, time stability, and the representativeness of an index site. *Water Resources Research*. 50:293-305. DOI: 10.1002/2012WR013038.

Winstral, A.H., Marks, D.G., Gurney, R. 2014. Assessing the sensitivities of distributed snow models to forcing data resolution. *Journal of Hydrometeorology* 15(4):1366-1383.

Zhang, Y., Cheng, G., Li, X., Han, X., Wang, L., Li, H., Chang, X., Flerchinger, G.N. 2013. Coupling of the simultaneous heat and water model with a distributed hydrological model and evaluation of the combined model in a cold region watershed. *Hydrological Processes* 27:3762-3776. DOI: 10.1002/hyp.9514.

Antibiotic resistance in soils receiving reclaimed municipal wastewater for groundwater recharge. The application of reclaimed municipal wastewater, which often contains antibiotics, could lead to increased antibiotic resistance in soil microorganisms receiving these waters. ARS researchers in Maricopa, Arizona, found that soil organisms isolated from the top 30 cm of a groundwater recharge facility were resistant to the antibiotics lincomycin, penicillin, and vancomycin, but the level of resistance in the recharge basins was similar to organisms from a recharge facility that only receives ground water for recharge. Furthermore, resistance to four antibiotics in *Enterococcus* was higher in the control soils that had only received groundwater than in soils receiving treated effluent. Analyzing the development of antibiotic resistance in soil bacteria at these two sites increases the awareness of potential environmental and public health impacts, or the lack thereof, of using reclaimed water for groundwater recharge and irrigation of municipal areas.

Mclain, J.E., Williams, C.F. 2014. Sustainability of water reclamation: long-term recharge with reclaimed wastewater does not enhance antibiotic resistance in sediment bacteria. *Sustainability* 6:1313-1327.

Deficit irrigation reduces water use in tree crops. California is under an extended and severe drought, and water available for irrigation has significantly decreased. In a multi-year field study, ARS researchers at Parlier, California, conducted deficit irrigation experiments in a peach orchard using drip, micro-sprinkler, and furrow irrigation methods, and controlled irrigation scheduling using real-time infrared canopy temperature measurements. The field study demonstrated the potential feasibility of managing deficit irrigation using infrared temperature sensors, without reducing yield or fruit quality. Deficit irrigation resulted in a potential water savings of up to 53%. When combined with water stress monitoring using infrared sensors,

deficit irrigation could also be useful in managing irrigation in other perennial tree crops, particularly during drought and/or other periods of limited water availability.

Zhang, H., Wang, D. 2013. Management of postharvest deficit irrigation of peach trees using infrared canopy temperature. *Vadose Zone Journal* 12(3):doi:10.2136/vzj2012.0093.

An improved ‘crop water use’ model to help reduce evaporation losses from croplands. As water availability from the Ogallala Aquifer declines, farmers will need to implement both irrigation and dry land farming strategies that maximize the efficiency of crop water use (i.e., transpiration), while minimizing evaporation from the soil. Because evaporation and transpiration are difficult to measure directly, ‘crop water use’ models are needed that can accurately calculate these two parameters. In collaboration with the Ben-Gurion University in Israel, ARS scientists from Bushland, Texas, and Beltsville, Maryland, found that a commonly used ‘crop water use’ model overestimated evaporation while underestimating transpiration. The team developed a revised model that improved the calculation of both evaporation and transpiration. The new model and the knowledge gained during its development will aid in the creation of new management practices to help reduce evaporation losses from crops, thus sustaining or enhancing crop production in areas where water is limiting.

Colaizzi, P.D., Agam, N., Tolk, J.A., Evett, S.R., Howell, T.A., Gowda, P., O’Shaughnessy, S.A., Kustas, W.P., Anderson, M.C. 2014. Two source energy balance model to calculate E, T, and ET: Comparison of Priestly-Taylor and Penman-Monteith formulations and two time scaling methods. *Transactions of the ASABE* 57(2):479-498.

The importance of riparian forest buffers to overall water consumption in regional watersheds in the southeastern U.S. Forested riparian buffers are prevalent throughout the Southeastern Coastal Plain Region of the U.S. Because they make up a significant portion of the regional landscape, transpiration within these riparian buffers impacts the hydrologic budgets of regional watersheds. ARS scientists at Tifton, Georgia, selected a riparian buffer along a first order stream in South-central Georgia for a sap velocity study designed to provide measurements of tree transpiration. Average annual transpiration for the studied area was 1175 mm per year, representing 86% of annual precipitation, and 88% of annual potential evapotranspiration, per unit area. These data suggest that compared to upland land covers, transpiration within regional buffers uses a disproportionate amount of water on a per area basis. This is an important consideration when examining overall water consumption in regional watersheds.

Bosch, D.D., Marshall, L.K., Teskey, R. 2014. Forest transpiration from sap flux density measurements in a Southeastern Coastal Plain riparian buffer system. *Agricultural and Forest Meteorology* 187:72-82. <http://dx.doi.org/10.1016/j.agrformet.2013.12.002>.

EROSION, SEDIMENTATION, AND WATER QUALITY PROTECTION

Surface and/or subsurface hydrologic transport of nutrients, pesticides, pathogens, and emerging pollutants can contaminate water resources and harm aquatic ecosystems. Interactions of land resource management practices with climate, soil, and landscape properties control the processes of sediment detachment, the fate and transformation of contaminants transported in both dissolved and sediment-associated states, and the impacts of these materials on aquatic ecosystems.

Selected Accomplishments

Controlling atrazine losses in agricultural watersheds underlain by restrictive layer (clay pan) soils. Atrazine is one of the most prevalent soil-applied herbicides used in corn cultivation, but its widespread use has led to significant contamination of surface and ground water resources across the U.S. Corn Belt. Restricted layer (clay pan) soils in northeastern Missouri are particularly vulnerable to the transport of both soil and atrazine in surface runoff. To better control atrazine losses in these landscapes, ARS scientists at Columbia, Missouri, assembled 15 years of data from the Goodwater Creek Experimental Watershed, analyzing stream flow and atrazine transport, developing a simple model to accurately simulate these processes, and then testing the model with 4 years of data from 7 additional watersheds planted with corn (5-24%) and treated with atrazine. Herbicide use intensity was the primary quantitative determinant of risk, allowing researchers to determine whether changes in herbicide load were due to producer management or simply prevailing weather conditions. As a mechanism for controlling atrazine loss, researchers isolated and confirmed the identity of an atrazine degrading compound from Eastern Gamagrass, shown in previous research to enhance atrazine degradation in soil compared to other forages. This research could lead to the development of a commercial product to enhance atrazine degradation in soils. Incorporation of soil-applied herbicides like atrazine reduces their transport in runoff, but often conflicts with erosion control measures (e.g. no-till) that preclude the incorporation of herbicides. A commercially available tillage implement (a rotary harrow) substantially reduced atrazine loss, but did not significantly increase erosion compared to no-till. In combination, this research provides key information on atrazine movement, particularly in restricted drainage soils, while providing tools to help farmers enhance atrazine degradation, preventing its loss in runoff while simultaneously maintaining the erosion-control benefits of reduced tillage. These findings have the potential to solve the region's two most persistent water quality problems, improving the sustainability of crop production while maintaining or increasing or farmer profitability.

Willett, C.D., Lerch, R.N., Lin, C., Goyne, K.W., Leigh, N.D., Roberts, C.A. 2013. Identification of an atrazine-degrading benzoxazinoid in Eastern gamagrass (*tripsacum dactyloides*). *Journal of Agricultural and Food Chemistry* 61:8026-8033. DOI: 10.1021/jf402271h.

Lerch, R.N., Harbourt, C.M., Broz, R.R., Thevary, T.J. 2013. Atrazine incorporation and soil erosion: balancing competing water quality concerns for claypan soils. *Transactions of the ASABE* 56(6):1305-1316. DOI:10.13031/trans.56.10272.

Sadler, E.J., Sudduth, K.A., Lerch, R.N., Baffaut, C., Kitchen, N.R. 2012. A simple index explains annual atrazine transport from surface runoff-prone watersheds in the north-central USA. *Hydrological Processes* 28:210-217. DOI: 10.1002/hyp.9544.

Seasonal trends in pesticide mixtures differ annually within channelized agricultural headwater streams. There is only a limited amount of information available on the presence of pesticide mixtures (i.e., combinations of two or more pesticides) in agricultural streams. Documentation of the characteristics of pesticide mixtures and their spatial and temporal trends (where and when they move in the landscape) is a critical first step in evaluating the risks of pesticide mixtures. ARS scientists at Columbus, Ohio, examined how the complexity, concentration, and types of pesticide mixtures differ spatially and temporally within channelized

agricultural headwater streams in central Ohio. Key findings indicated that many characteristics of pesticide mixtures exhibited seasonal trends that differed annually. These results represent the first comprehensive documentation of the spatial and temporal trends in pesticide mixtures within agricultural streams, highlighting the variable nature of the timing of pesticide movement. The results could be used to design ecotoxicology studies of the impacts of pesticide mixtures on the biota within these small, degraded streams. Because they provide empirical evidence that supports the need for implementing watershed management plans that target the reduction of multiple pesticides within channelized agricultural headwater streams, these results will also be valuable to watershed managers.

Smiley, P.C., King, K.W., Fausey, N.R. 2014. Annual and seasonal differences in pesticide mixtures within channelized agricultural headwater streams in central Ohio. *Agriculture, Ecosystems and Environment* 193:83-95.

Mitigating the impact of climate change on soil erosion. In central Oklahoma, both precipitation and the frequency of extreme events have increased over the last decades and should continue to increase in the future. Special concerns arise in that current soil and water conservation efforts, based largely on climate observations and agronomic practices of the past century, will not keep pace with these climatic changes. ARS researchers at El Reno, Oklahoma, investigated options to mitigate the impacts of climate change on soil erosion and sediment yield for winter wheat crops in central Oklahoma. A computer simulation investigation suggested that wide implementation of conservation tillage could offset a large portion of the anticipated increase in sediment yield. However, to overcome the large uncertainty in projected climate, more effective conservation measures (e.g., terraces or no-till) may be necessary to ensure that future sediment yield from winter wheat fields remains close to today's levels.

Garbrecht, J.D., Zhang, X.J., Steiner, J.L. 2014. Climate change and observed climate trends in the Fort Cobb experimental watershed. *Journal of Environmental Quality* 43:1319-1327.

Simulation of dam-break processes for reservoirs and levee-breaching cases under complex river-flooding conditions. The ARS dam break simulation model, WinDAM, was integrated into the Center for Computational Hydroscience and Engineering 2 Dimensional (CCHE2D) model using physically-empirically based key dam-break mechanisms of WinDAM and all the necessary hydrodynamic calculations of the CCHE2D model. The integration makes it possible to simulate dam-break processes of reservoirs and levee breaching in cases for complex river flooding conditions. The computed flow is two dimensional, with more realistic flow patterns and simultaneous simulation of multiple breaching. Adding this new capability to the NCCHE Graphic User Interface, allows users to simulate dam break and levee-breaching processes, and visualize simulation results, interactively, thereby improving both dam management and public safety.

Ding, Y., Elgohry, M., Altinakar, M., Wang, S. 2013. Simulation of morphological changes due to dam removal. In: Khan, A.A. and Wu, W. *Sediment Transport: Monitoring, Modeling and Management*. Nova Science Publishers, New York, p. 213-238. Available: www.novapublishers.com/catalog/product_info.php?products_id=41291

Gully erosion control structures can restore riparian habitat for small mammals within agricultural watersheds. Within agricultural watersheds in the southeastern United States,

expanding agriculture, stream channelization, and gully erosion have reduced habitat quality for small mammals in riparian habitats. Currently in Mississippi, the installation of erosion control structures (drop pipes) at the riparian zone-agricultural field interface halts gully erosion and simultaneously establishes one of four riparian habitat types. Differences in small mammal habitat use among these four riparian habitat types were unknown. ARS scientists at Columbus, Ohio, evaluated small mammal community and population structure in the four riparian habitat types created by drop pipe installation. Small mammal diversity and abundance were greatest when drop pipe installation resulted in riparian habitats that were greater than 1000 square meters in area, had greater than 21% coverage with woody vegetation greater than 1.8 m tall, and supported water-storage pool volumes greater than 41 cubic meters. Current drop-pipe installation practices focus on erosion control without consideration of habitat creation. Altering installation design to improve the effectiveness of creating riparian habitats would increase the ecological benefits resulting from this conservation practice. State, federal, and private agencies could use this information for managing agricultural watersheds and restoring streams.

Smiley, P.C., Cooper, C.M. 2013. Small mammal habitat use within restored riparian habitats adjacent to channelized streams in Mississippi. *Journal of Environmental Protection* 4:1280-1291.
DOI:10.4236/jep.2013.411149.

IMPROVING CONSERVATION EFFECTIVENESS

The magnitude of annual Federal expenditures for conservation programs (at least \$4B per year) necessitates evaluation of the cost of conservation practices implemented through those programs in comparison with the environmental benefits they provide. While examining the effects of existing practices can provide a retrospective analysis of prior expenditures, researchable questions remain as to how new practices can be developed, and existing and new practices implemented, to improve the benefits achieved with available funds. The demands for information from ongoing research projects like the Conservation Effects Assessment Project (CEAP), and regional initiatives such as in the Mississippi River Basin (MRBI) and the Chesapeake Bay (CBI), demonstrate the continuing need to assess and improve the benefits of conservation practices.

Selected Accomplishments

Mitigating phosphorus losses from tile-drained landscapes to ensure the availability of safe drinking water supplies. The Midwestern U.S. has some of the most productive agricultural soils in the world, but much of this region would be unable to support agriculture without drainage; high water tables would both damage crops and prevent the access of machinery to the fields at critical times. Drainage (e.g., tile drains) removes excess water as quickly as possible, but it can also cause the rapid export of agrochemicals, particularly phosphorus that can subsequently degrade the quality of key drinking water supplies. Since 2008, ARS scientists at West Lafayette, Indiana, have monitored both surface and tile discharges from agricultural fields in the St. Joseph River watershed in northeast Indiana. In contrast to the traditional understanding of tile drainage that suggests materials move slowly through soils to the tiles, peak water flow through the tiles occurred at the same time as peak surface runoff, suggesting a strong surface connection through large soil pores called macro-pores. Firstly, as part of the

Conservation Effects Assessment Project (CEAP), scientists working in the St. Joseph River Watershed compared the effects of two conservation practices (no-till and reduced-till) on water quality. No-till reduced losses of all water quality pollutants except soluble phosphorus. A second APEX modeling study, conducted in collaboration with the Greater Wabash River Resource Conservation and Development Council at the Wildcat Creek Watershed (also in Indiana), evaluated how the incorporation of additional conservation practices might be used to improve water quality. The modeling predicts that both forages and cover crops, which treat surface as opposed to subsurface waters, further reduce both nitrogen and phosphorus losses in runoff, providing information on how government-supported conservation practices can help reduce phosphorus losses from tile-drained croplands in conservation tillage (i.e., no till). As researchers, policy makers, and farmers search for ways to reduce P loadings to surface waters, such as Lake Erie, to prevent episodes such as occurred in 2014 that temporarily shut down the city of Toledo's drinking water supply, these studies highlight the importance of treating both surface runoff and tile drainage to minimize harmful algal blooms.

Smith, D.R., King, K.W., Johnson, L., Francesconi, W., Richards, P., Baker, D., Sharpley, A.N. 2014. Surface runoff and tile drainage transport of phosphorus in the Midwestern United States. *Journal of Environmental Quality*. DOI:10.2134/jeq2014.04.0176.

Francesconi, W., Smith, D.R., Heathman, G.C., Wang, X., Williams, C. 2014. Monitoring and APEX modeling of no-till and reduced-till in tile drained agricultural landscapes for water quality. *Transactions of the ASABE* 57(3):777-789.

Elevated carbon dioxide (CO₂) further lengthens growing season under warming conditions. Climate warming is changing forage availability on rangelands. In order to adjust management practices appropriately, land managers need a better understanding of the effects of elevated CO₂ on conditions such as length of growing season. ARS scientists at Fort Collins, Colorado, in collaboration with Colorado State University researchers, evaluated the effects of both elevated CO₂ and temperature on the development of temperate grassland species under a Free-Air CO₂ Enrichment (FACE) system. Warming resulted in a longer growing season, due to earlier leaf emergence in some species or delayed senescence in others. By conserving water, elevated CO₂ further extended the growing season, but not the reproductive season, enabling most species to remain active longer. These experimental results will make model parameters and simulation of phenology more accurate in different plant growth and hydrologic watershed models under ambient as well as projected elevated CO₂ concentrations and warming. The team published its findings in the prestigious journal *Nature*.

Reyes-Fox, M.A., Steltzer, H., Trlica, M., McMaster, G.S., Andales, A., Lecain, D.R., Morgan, J.A. 2014. Warming and elevated CO₂ lead to longer growing season in temperate grassland. *Nature* 510:259-269. DOI:10.1038/nature13207.

Multiple combined best management practices (BMPs) reduce sediments and increase lake water clarity. There is a need for better understanding of how effective agricultural BMPs are at the watershed level. ARS scientists in Oxford, Mississippi, studying how agricultural BMPs improve water quality, measured water clarity, total suspended sediment, and total dissolved solids in Beasley Lake, a Conservation Evaluation Assessment Project (CEAP) watershed in the Mississippi Delta, from 1996 to 2009. Results showed the effect of BMPs put in place from 1997-2006—including within-field, edge-of-field, and Conservation Reserve Program (CRP)

practices. Over the 14-year study, the lake had clearer water, less suspended sediments, and lower dissolved solids, coinciding with the areal extent of BMPs put in place. Changes were most evident during spring. By providing additional information to improve and sustain lake and flood plain water quality and overall environmental quality through the use conservation practices, these results have broad relevance for regulatory and other agencies and farming stakeholders.

Lizotte Jr, R.E., Knight, S.S., Locke, M.A., Bingner, R.L. 2014. Influence of integrated watershed-scale agricultural conservation practices on lake water quality. *Journal of Soil and Water Conservation* 69(2):160-170.

Grazing winter rye cover crops in no-till cotton can provide net positive returns in the southeastern U.S. In the southeastern U.S., cover crop use is limited due to concerns of establishment costs and possible negative effects on subsequent crops. From 2005 to 2009, ARS researchers conducted a study near Watkinsville, Georgia, to test the hypothesis that gains from grazing cover crops can offset establishment costs without reducing yield. Differences between grazed and non-grazed returns ranged from -\$26 to \$335. The average was \$110 per hectare when based on 2012 market year prices. Although negative effects of soil compaction were observed in the final year, returns from grazing do have the potential to offset establishment costs of a rye cover crop, increasing profits from cotton production in southeastern U.S by an average of \$110 per hectare (i.e., approximately \$45 per acre).

Schomberg, H.H., Fisher, D.S., Reeves, D.W., Endale, D.M., Raper, R.L., Jayaratne, K., Gamble, G.R., Jenkins, M. 2014. Grazing winter rye cover crop in a cotton no-till system: yield and economics. *Agronomy Journal* 106:1041-1050. DOI:10.2134/agronj13.0434.

Saturated buffers improve nitrate removal in tile-drained landscapes. Streamside buffers are a proven practice for removing nitrate from both overland flow and shallow groundwater before it can enter the stream. However, in landscapes with tile drainage, most of the subsurface flow leaving farmers' fields is through the tiles, bypassing the buffers and thus providing little opportunity for associated nitrate removal. ARS scientists in Ames, Iowa, showed that re-routing a fraction of field tile drainage from a 25 acre field through a riparian buffer as subsurface flow removed more than 250 pounds of nitrate-nitrogen each year; nitrogen that would otherwise enter surface waters. Saturated buffers are a promising management practice for improving surface water quality within tile-drained, agricultural landscapes; wide spread adoption could remove millions of pounds of nitrate, preventing it from entering the Nation's surface waters.

Jaynes, D.B., Isenhardt, T.M. 2014. Reconnecting tile drainage to riparian buffer hydrology for enhanced nitrate removal. *Journal of Environmental Quality* 43:631-638.

IMPROVING WATERSHED MANAGEMENT AND ECOSYSTEM SERVICES IN AGRICULTURAL LANDSCAPES

Society relies on adequate freshwater resources to support households, agriculture, industry, wildlife habitat, aquatic ecosystems, and a healthy environment. Eighty-seven percent of the nation's drinking water flows over or through agricultural lands. Agricultural watersheds, including crop, pasture, and range lands, cover over 70% of the continental U.S. In the 21st

century, unprecedented demands for freshwater, rapidly changing land use, recurring droughts, regional climatic variations, and new demands for energy production on working lands mean that the Nation's freshwater resources are at risk now more than ever before. A primary concern of ARS customers, stakeholders, and partners is the accurate quantification and management of our water resources to support people, agriculture, and the environment, across heterogeneous agricultural and urban landscapes. At the watershed or landscape scale, the provision of ecosystem services (e.g., agricultural production, a clean and abundant water supply, improved wildlife habitat, greenhouse gas reduction, soil stabilization, recreational opportunities, reduced energy consumption, and reduction of urban wastes) can involve multiple stakeholders with conflicting objectives. Because simultaneously optimizing for even two objectives involves compromise, integrated watershed and landscape management is thus a complex task, but necessary not only to support the goals of legislation such as the Clean Water and Endangered Species Acts, but also to address the concerns of watershed coalitions, policy makers, and the public.

Selected Accomplishments

Operational implementation of a global root-zone soil moisture monitoring system. Soil moisture is a key component of Earth's water cycle that is essential for plant life, affects global energy flux, and influences weather and climate. Monitoring the availability of soil moisture in the rooting zone is critical for forecasting variations in agricultural productivity (e.g., as related to drought) that affect global food prices and food availability. Satellite measurements of soil moisture have the potential to provide this information frequently and globally. ARS scientists at Beltsville, Maryland, designed an optimized system for globally estimating the availability of soil moisture in the rooting zone, producing new worldwide soil moisture maps that reveal how the wetness of the land fluctuates seasonally and with changes in weather. These maps are now available to the public to support a wide range of agricultural and hydrologic applications, from advancing climate models and weather forecasts to improving flood-warning systems. Since April 2014, USDA Foreign Agricultural Service analysts have been using predictions from this system to improve their operational forecasts of global agricultural yield and productivity. These forecasts are of critical importance for providing unbiased information to commodity markets, and for providing decision makers with critical crop production information related to potential food deficits linked to severe drought, identifying countries that may require food aid assistance.

Panciera, R., Walker, J.P., Jackson, T.J., Ryu, D., Gray, D., Monerris, A., Yardley, H., Tanase, M., Rudiger, C., Wu, X., Gao, Y., Hacker, J. 2014. The soil moisture active passive experiments (SMAPEX): Towards soil moisture retrieval from the SMAP mission. *IEEE Transactions on Geoscience and Remote Sensing* 52:490-507.

Leroux, D., Kerr, Y., Sahoo, A., Wood, E., Bindlish, R., Jackson, T.J. 2014. An approach to constructing a homogeneous time series of soil moisture using SMOS. *IEEE Transactions on Geoscience and Remote Sensing* 52:393-405.

Leroux, D., Kerr, Y., Bitar, A., Gruhier, C., Bindlish, R., Jackson, T.J., Berthelot, B., Portet, G. 2014. Comparison between SMOS, VUA, ASCAT, and ECMWF soil moisture products over four watersheds in the U.S. *IEEE Transactions on Geoscience and Remote Sensing* 52:1562-1571.

Mladenova, I., Jackson, T.J., Njoku, E., Bindlish, R., Chan, S., Cosh, M.H., Holmes, T.R., De Jeu, R., Jones, L., Kimball, J., Paloscia, S., Santi, E. 2014. Remote monitoring of soil moisture using passive

microwave-based technologies – theoretical basic and overview of selected algorithms for AMSR-E. *Remote Sensing of Environment* 197-213.

Ochsner, T., Cosh, M.H., Cuenca, R., Dorigo, W.A., Draper, C., Hagimoto, Y., Kerr, Y., Larson, K., Njoku, E., Small, E., Zreda, M. 2013. State of the art in large-scale soil moisture monitoring. *Soil Science Society of America Journal* 77(6):1888-1919.

Bruscantini, C., Perna, P., Ferrazoli, P., Gringis, F., Karszenbaum, H., Crow, W.T. 2014. Effect of forward/inverse model asymmetries over retrieved soil moisture assessed with an OSSE for the Aquarius/SAC-D. *Journal of Applied Remote Sensing (JARS)* 50(1):371-375.

Rowlandson, T., Berg, A., Bullock, P., Ojo, E.R., McNairn, H., Wiseman, G., Cosh, M.H. 2013. Evaluation of several calibration procedures for a portable soil moisture sensor. *Journal of Hydrology* 498:335-344.

A 50+ year data record for the Upper Washita River Watershed. While hydrologic processes and scientific investigations related to sustainable agricultural systems rely on universal principles, research to understand processes and evaluate management practices is often site-specific in order to achieve a critical mass of expertise and research infrastructure to address spatially, temporally, and ecologically complex systems. In the face of dynamic climate, market, and policy environments, long-term research is required to understand and predict risks and possible outcomes of alternative scenarios. ARS researchers at El Reno, Oklahoma, their collaborators from the U.S. Geological Survey and USDA Natural Resources Conservation Service, published a collection of data and research papers describing long-term research (1961 to present) in the Upper Washita River basin of Oklahoma. The data papers document datasets in detail (weather, hydrology, physiography, land cover, and sediment and nutrient water quality); associated research papers present analyses based on those data. The data set represents a living history of research to engage collaborative science across institutions and disciplines, helping scientists further explore complex, interactive processes and systems. The following potential areas of future research have been identified: 1) resilience to current and future climate pressures; 2) sources, fate, and transport of contaminants at the watershed scale; 3) linked atmospheric-surface-subsurface hydrologic processes; 4) high spatiotemporal resolution analyses of linked hydrologic processes; and 5) multiple-objective decision making across linked farm to watershed scales.

Moriasi, D.N., Starks, P.J., Guzman Jaimes, J.A., Garbrecht, J.D., Steiner, J.L., Stoner, C.J., Allen, P.B., Naney, J.W. 2014. Upper Washita River experimental watersheds: Reservoir, groundwater, and stream flow data. *Journal of Environmental Quality* 43:1262-1272.

Moriasi, D.N., Starks, P.J., Steiner, J.L., Guzman Jaimes, J.A., Allen, P.B., Naney, J.W. 2014. Upper Washita River experimental watersheds: Physiography data. *Journal of Environmental Quality* 43:1298-1309.

Starks, P.J., Fiebrich, C.A., Grimsley, D.L., Garbrecht, J.D., Steiner, J.L., Guzman Jaimes, J.A., Moriasi, D.N. 2014. Upper Washita River Experimental watersheds: Meteorologic and soil climate measurement networks. *Journal of Environmental Quality* 43:1239-1249.

Starks, P.J., Steiner, J.L., Moriasi, D.N., Guzman Jaimes, J.A., Garbrecht, J.D., Allen, P.B., Naney, W.J. 2014. Upper Washita River experimental watersheds: Nutrient water quality data. *Journal of Environmental Quality* 43:1280-1297.

Steiner, J.L., Starks, P.J., Garbrecht, J.D., Moriasi, D.N., Zhang, X.J., Schneider, J.M., Guzman Jaimes, J.A., Osei, E. 2014. Long-term environmental research: The Upper Washita River experimental watersheds, Oklahoma, USA. *Journal of Environmental Quality* 43:1227-1238.

Cosh, M.H., Starks, P.J., Guzman Jaimes, J.A., Moriasi, D.N. 2014. Upper Washita River experimental watersheds: Multiyear stability of soil water content profiles. *Journal of Environmental Quality* 43(4):1328-1333, DOI: 10.2134/jeq2013.08.0318.

U.S. grassland mortality increased following early 21st-century drought. ARS researchers in Tucson, Arizona, found that the early 21st century drought in the southwestern United States resulted in an exceptional decrease in grassland growth, and the replacement of native grasses with less-nutritious and more-fire-prone invasive grasses. Their study utilized in-situ measurements of surface soil moisture and precipitation, combined with satellite estimates of above ground net primary production, in six USDA experimental grasslands in Utah, New Mexico, Arizona, Colorado and Oklahoma. This is the first report of how U.S. grasslands may respond to the regional drying and warming predicted with climate change. The analysis has two important implications: 1) it provides ranchers with new information for managing grasslands under predicted climate change to lower fire risk, minimize the loss of forage, and retain ecosystem services; 2) it suggests that grasslands can serve as an early indicator of impending climate change. These compelling results in a natural setting at the regional scale should play an important role in future grassland research, management and policy.

Moran, M.S., Ponce Campos, G., Huete, A., McClaran, M., Zhang, Y., Hamerlynck, E.P., Augustine, D.J., Gunter, S.A., Kitchen, S.G., Peters, D.C., Starks, P.J., Hernandez, M. 2014. Functional response of U.S. grasslands to the early 21st century drought. *Ecology* 95:2121-2133.

Cropping system impacts on nutrient concentrations in soil water. An ARS scientist in Ames, Iowa, collaborated with an Iowa State University faculty member in an eight-year study to compare nutrient concentrations in soil water beneath cropping rotations including a two-year corn and soybean rotation, a three-year corn-soybean-oat/clover rotation, and a four-year corn-soybean-oat/alfalfa-alfalfa rotation. Their results showed that changes to cropping systems can reduce nutrient losses associated with annual row crops. While nitrate losses beneath perennial crops like alfalfa are generally small, this research showed that for alfalfa grown in a rotational system, benefits carry over to the following corn crop. There was also evidence to show that using perennial crops in rotation with annual crops reduces phosphorus losses. A four-year rotation is most feasible for farms that integrate crop and livestock production. The finding that crop rotations can moderate losses of both nitrogen and phosphorus to receiving waters is of interest to the agricultural and conservation communities.

Tomer, M.D., Liebman, M. 2014. Nutrients in soil water under three rotational cropping systems, Iowa, USA. *Agriculture, Ecosystems and Environment* 186:105-114.

Ability to simulate erosion on disturbed rangelands improved. As there is no generally accepted erosion prediction model for rangelands, a long-term goal has been the development of the Rangeland Hydrology and Erosion Model (RHEM). The greatest danger of erosion, but most difficult to simulate, is following major disturbance, such as a fire. ARS researchers in Tucson, Arizona, and Boise, Idaho, developed empirical equations that predicted splash and sheet flow detachment based on ground and vegetation cover. RHEM was able to match the predicted effects of disturbances and treatments across a wide range of vegetation and ground cover

conditions immediately after fire. The improved splash and sheet flow erosion modeling approach in RHEM creates a practical management tool for quantifying erosion and assessing erosion risk following rangeland disturbance. The enhancements to RHEM expand its applicability as a practical land management tool for conservation planning and quantifying environmental benefits of alternative conservation practices.

Al-Hamdan, O.Z., Hernandez, M., Pierson Jr, F.B., Nearing, M.A., Williams, C.J., Stone, J.J., Boll, J., Weltz, M.A. 2014. Rangeland Hydrology and Erosion Model (RHEM) enhancements for applications on disturbed rangelands. Hydrological Processes DOI: 10.1002/hyp.10167.