Water Availability and Watershed Management National Program (NP 211)
FY 2013 Annual Report

Problem Area 1 – Effective Water Management in Agriculture

1A. Irrigation Scheduling Technologies for Water Use Efficiency

New version of PhenologyMMS improves simulation of plant developmental responses to water deficits. Crop models help farmers manage water efficiently for optimal crop production. Modeling spatial relationships in plant growth and yield at field-to-watershed scales requires the accurate simulation of crop development across the landscape in response to variations in soil water, temperature, and other factors. To address this need, ARS scientists in Fort Collins, Colorado, developed and released Version 1.3 of the Phenology Modular Modeling System decision support tool that allows the timing of farm crop management practices with crop development stage, thereby increasing agricultural production while reducing adverse environmental impact. The new version has an enhanced user interface and improved underlying science code. It adds new crop species, a larger set of default parameters, and more historical weather data. PhenologyMMS has already been downloaded by more than 1,500 researchers, farmers, and agribusinesses, and is being used by commodity groups such as the Colorado Association of Wheat Growers and on Nebraska farms as part of the Nebraska Water Balance Alliance.

McMaster, G.S., J.C. Ascough II, D.A. Edmunds, D.C. Nielsen, and P.V. Prasad. 2013. Simulating crop phenological responses to water stress using the Phenology MMS software component. Applied Engineering in Agriculture 29(2): 233-249.

Sunflower—an alternative crop for lands with marginal irrigation capacity in the Central High Plains. As water availability in the Ogallala Aquifer decreases, new crops and/or farming practices will be needed to use available irrigation water efficiently. Because of its shorter growing season and therefore lower overall irrigation needs, sunflower is a crop of interest in the Ogallala region. In collaboration with researchers at Kansas State University, ARS scientists in Bushland, Texas, studied the response of sunflower grown in northwest Kansas to three irrigation regimes. Sunflower seed yields were not appreciably affected by decreasing the irrigation regime from 1 inch every 4 days to 1 inch every 12 days. These results suggest that optimal sunflower seed yields can be achieved while conserving one-third to one-half of the irrigation water. Sunflower appears to be a good candidate for cropping in Central High Plains regions with marginal irrigation capacity.

Klocke, N.L., R.S. Currie, D.J. Tomsicek, and J.W. Koehn. 2012. Sunflower response to irrigation from limited water supplies with no-till management. Transactions of the ASABE 56(1):167-175.

1B. Water Productivity at Multiple Scales

Wireless soil moisture and weather monitoring for crop water management. If soil moisture and plant physiological responses to water stress can be accurately measured, crop water status and the amount of irrigation needed to support adequate crop growth can be accurately estimated, thereby increasing the efficiency of irrigation water use. ARS scientists in Stoneville,

Mississippi, developed and deployed a field-based wireless sensor network (WSN), consisting of multiple soil moisture sensors, weather sensors, radio data loggers, a wireless modem, and antenna mounts, to increase the efficiency of irrigation scheduling. The WSN has the capability to collect soil moisture and weather data from fields, and make these data accessible in real time via the internet. During a two year field evaluation period, data collected by the WSN have been used for irrigation scheduling in cotton, corn and soybean crops. Wireless sensor networks have the potential to improve the efficiency of water management in support of agricultural crop production.

Sui, R., J.A. Thomasson, and Y. Ge. 2012. Development of sensor systems for precision agriculture in cotton. International Journal of Agricultural and Biological Engineering 5(4):1-14.

1C. Irrigation Application Methods

State-wide network of sites will monitor agricultural water quantity and quality. Understanding agriculture's impact on water resources is imperative to improving management and policy associated with the production of food, fiber, feed and fuel. Working with State partners, ARS scientists in Jonesboro, Arkansas, established a network of edge-of-field monitoring sites to collect water resource information in 30 fields across 12 farms, representing Arkansas's major agricultural commodities. As producers begin to understand the makeup of the runoff from their fields, the information collected from these sites will help to improve management practices and to reduce excess nutrients and sediment entering local and regional waterways.

Reba, M.L., M. Daniels, Y. Chen, A. Sharpley, J. Bouldin, T.G. Teague, P. Daniel, and C.G. Henry. 2013. A statewide network for monitoring agricultural water quality and water quantity in Arkansas. Journal of Soil and Water Conservation 68(2):45A-49A.

1D. Dryland/Rainfed Water Management

Crop identified for in situ precipitation catchment forage production. Playas are ephemeral lakes—depressions that flood with runoff from the surrounding uplands after periods of intense or prolonged rainfall, and are characteristic of the Southern High Plains. Playas occupy 3 to 5% of the land area in this region, but are at best marginal farmlands, primarily because of their unpredictable flooding regimes and clayer soils. ARS researchers from Lubbock, Texas, examined whether eastern gamagrass—a flood-tolerant native forage species—could be used as part of a forage production system that made use of precipitation runoff from surrounding areas. Eastern gamagrass seeds are especially well suited to playas and can withstand long periods of flooding. The study demonstrated that eastern gamagrass plants can grow on playa soils and survive both infrequent flooding and prolonged periods of drought. The results clearly demonstrate that this species is capable of growth in these wetlands and might be incorporated into a precipitation-catchment forage production system, or as part of other wetland restoration or development efforts.

Gitz, D.C., J.T. Baker, J.E. Stout, D.K. Brauer, J.P Velten, and R.J. Lascano. 2013. Suitability of eastern gamagrass for in situ precipitation catchment forage production in playas. Agronomy Journal 105(4):907-914.

1E. Drainage Water Management and Control

Drainage water management increases corn and soybean yields. In order for farmers to adopt drainage water management, knowledge of its mean yield performance as well as its yield stability across different crop production environments is essential. Based on data analysis from 23 different combinations of crop, soil, and weather environments, the implementation of drainage water management in northwest Ohio significantly improved corn, popcorn, and soybean yields. In fields where drainage water management had been implemented, water tables were closer to the effective root zone for longer periods during the growing season than in fields with conventional unrestricted free drainage. In other words, raised water tables in the field resulted in increased crop yields. In cooperation with Ohio State University scientists, ARS scientists in Columbus, Ohio, were able to demonstrate that across multiple environments in northwest Ohio, drainage water management provides a yield advantage over conventional free drainage, while additionally providing water conservation and water quality benefits. The yield advantage of drainage water management gives farmers a financial incentive to adopt this practice.

Ghane, E., N.R. Fausey, V.S. Shedekar, H. Piepho, Y. Shang, and L.C. Brown. 2012. Crop yield evaluation under controlled drainage in Ohio, United States. Journal of Soil and Water Conservation 67(6):465-473.

Nitrogen and phosphorus transport in runoff from fairway turf. The enrichment of surface waters with excess nutrients from agriculture and other sources is associated with increases in algal blooms, euthrophication, and the development of hypoxic zones, such as the one that occurs annually in the northern Gulf of Mexico. The runoff of excess fertilizers is one of these sources. Management strategies used to maintain turf on golf courses and recreational fields often include both aerification (aeration?)and the application of fertilizer. Research exists on the effects of both hollow tine core cultivation (HTCC) and verticutting (VC) to reduce thatch on the transport of applied fertilizers in runoff, but there are no studies that report the effects of coupling these two management practices. ARS scientists in St. Paul, Minnesota, found either no reduction or an enhancement of risk associated with surface water concentrations of phosphorus or nitrogen in runoff from creeping bentgrass turf that was managed with HTCC+VC compared to HTCC alone. These findings will help grounds superintendents select best management practices, while providing scientists with data relating runoff to land management for watershed-scale modeling.

Rice, P.J., Horgan, B.P. 2013. Evaluation of nitrogen and phosphorus transport with runoff from fairway turf managed with hollow tine core cultivation and verticutting. Science of the Total Environment 456-457(2013):61-68.

1F. Use of Degraded Waters

S**orption of the antibiotic lincomycin to soils in arid regions depends on soil pH.** The reuse of sewage effluent for irrigation is an effective way to increase water supplies in the desert southwest. Contaminants such as antibiotics, found in treated effluent, have been identified as a potential problem for use of this water for irrigation. ARS scientists in Maricopa, Arizona, determined environmental fate parameters for lincomycin in three arid region soils. Lincomycin sorption was found to be related to soil pH. At pHs below 7.6, lincomycin exhibited little sorption to soil, but at pHs greater than 7.6, the sorption of lincomycin increased 10 fold. These results will help in determining site-specific guidelines for the disposal and use of reclaimed

water in arid regions.

Problem Area 2 – Erosion, Sedimentation, and Water Quality Protection

2A. Field Scale Processes Controlling Contaminant Fate and Transport

Late summer application of poultry litter minimizes potential increases in *E. coli* concentrations in runoff. Fecal bacterial contamination of surface waters is a critical water quality concern that has serious human health implications. Poultry litter application is often assumed to be major contributor to bacterial contamination; grazing lands often receive a similar focus. In a three year study of water quality in 13 watersheds, ARS investigators in Temple, Texas, found that poultry litter applications did not impact *E. coli* concentrations in runoff. Late summer application of poultry litter minimizes *E. coli in* runoff following application, because the hot, dry conditions that characterize this period are unfavorable for *E. coli* survival. Cultivated watersheds, both with and without litter application, produced the lowest *E. coli* concentrations in runoff, presumably due to limited wildlife presence and livestock exclusion. In contrast, an ungrazed native prairie reference site produced comparatively high concentrations of *E. coli* in runoff, presumably due to increased fecal deposition from abundant wildlife. High concentrations of *E. coli* observed in runoff from grazed lands emphasize the need for livestock producers to follow best management practice recommendations to minimize bacterial contributions to runoff.

Harmel, R.D., K.L. Wagner, E. Martin, T. Gentry, R. Karthikeyan, M. Dozier, and C. Coufal. 2013. Impact of poultry litter application and land use on E. coli runoff from small agricultural watersheds. Biological Engineering Transactions (ASABE) 6(1):3-16.

2B. Quantify and Predict In-Stream Processes

Improved prediction of transport rates of sands released from reservoirs. Prolonged erosion of farm fields and hill slopes has greatly reduced the storage capacity of reservoirs and the structural integrity of dams. Common mitigation measures include removing dams, or flushing stored sediments from behind dams, releasing sands into sand-deprived river reaches. Because they assume that the released sediments are available on the riverbed, current equations for calculating downstream transport rates are not accurate. ARS scientists at Oxford, Mississippi, developed a new transport relation by recreating sand transport over immobile gravel and cobble beds, typically found downstream from dams. The new relation uniquely links sand transport to the surface characteristics of the gravel and cobble riverbed, improving both predicted transport rates and resulting riverbed and flood elevations. Through this research, both the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers have been provided with a tool to more accurately evaluate dam removal and sediment flushing alternatives.

Kuhnle, R.A., D.G. Wren, E.J. Langendoen, and J.R. Rigby Jr. 2013. Sand transport over an immobile gravel substrate. Journal of Hydraulic Engineering 139(2):167-176.

2C. Ecological Response to Improved Water Quality

Watershed-wide conservation practices reduce the risk of pesticides to aquatic organisms. ARS scientists in Oxford, Mississippi, examined pesticide contamination in lake surface water and the associated risk to aquatic animals and algae in relation to conservation and cropping practices within the watershed of an oxbow lake in the Mississippi Delta from 2000 to 2009. Thirteen pesticides in lake surface waters were examined. During the ten-year study period, crops changed from mostly cotton in 2000-2001, to mostly soybean in 2002-2004, 2006, 2008, and 2009, with mostly milo and corn in 2007. Conservation practices such as reduced tillage began in 2001; Conservation Reserve Program enrollment began in 2003 with the planting of cottonwood trees. Over the ten-year study period, the risk to lake aquatic animals and algae was greatest in 2000-2002, lowest in 2005-2006, and low in 2007-2009. Overall, lake water pesticide contamination decreased annually until 2005-2006 and increased again in 2007-2009 due, in part, to the replacement of reduced tillage soybeans with conventional-till milo and corn in 2007. These results are of interest to regulatory agencies and the pesticide industry by providing additional information to improve and sustain lake and flood plain water quality and overall environmental quality using conservation practices.

Lizotte Jr., R.E., S.S. Knight, M.A. Locke, and R.W. Steinriede Jr. 2011. Ten-year assessment of agricultural management and land-use practices on pesticide loads and risk to aquatic biota of an oxbow lake in the Mississippi Delta, USA, 349-371. In: B. Hendriks (ed.) Agricultural Research Updates. New York, NY: Nova Publishers, Vol. 2. 478 pages.

2D. Development and Testing of Cost-effective Control Measures for Agriculture, Urban, and Turf Systems

Prairie grasses and compost improve urban soil. Compacted soils, such as those found in urban construction sites, reduce lawn growth and increase runoff and soil erosion. ARS scientists in Ames, Iowa, showed that soil was improved by mixing compost with the topsoil to a depth of 6 inches, and by planting buffalo grass and blue gamma grass. In general, planting native prairie grasses and composting proved beneficial to highly disturbed urban soils. Compared with the control lawn, treatments improved water holding capacity, eliminated sediment loss, and increased the penetration of roots into more dense subsoils. This information will aid developers in minimizing impacts of urban construction on runoff hydrology and sediment loss, reducing flooding and water-use impairments downstream. (NP211, C2, PS2d, PM 6.1.1, Project No 3625-13000-010-00D).

Hernandez-Santana, V., X. Zhou, M.J. Helmers, H. Asbjornsen, R. Kolka, and M.D. Tomer. 2013. Native prairie filter strips reduce runoff from hillslopes under annual row-crop systems, Iowa USA. Journal of Hydrology 477:94-103.

Problem Area 3 – Improving Conservation Effectiveness

3A. Improving Our Understanding of the Aggregate Effects of Conservation Practices at the Watershed Scale

Herbicide transport depends on the timing of application, enhanced degradation rates, and the presence of buffers. Agrichemical transport to coastal waters can have adverse ecological impacts. As part of the Conservation Effects Assessment Project (CEAP), ARS researchers at Tifton, Georgia, used a combination of field studies and simulation modeling to understand

atrazine fate and transport in a watershed adjacent to Puerto Rico's Jobos Bay National Estuarine Research Reserve. Most of the atrazine that moved toward the estuary was carried in surface runoff from tropical storms. Modeling studies demonstrated that the majority of atrazine transported was in dissolved form, and that under high rainfall and runoff conditions, riparian buffers were less effective at intercepting the herbicide before it reached the estuary. Transport to the estuary was also limited by rapid atrazine dissipation in field (crop) soils, suggesting that atrazine runoff is most likely to occur when a tropical storm event immediately follows atrazine application. Understanding the conditions under which atrazine and other herbicides are likely to be transported from agroecosystems to sensitive coastal waters helps farm managers develop practices that can reduce or eliminate the negative impacts of agrichemicals on important estuaries like Jobos Bay.

Potter, T.L., D.D. Bosch, A. Dieppa, D.R. Whitall, and T.C. Strickland. 2013. Atrazine fate and transport within the coastal zone in southeastern Puerto Rico. Marine Pollution Bulletin. 67:36-44.

Williams, C.O., R.R. Lowrance, D.D. Bosch, J.R. Williams, A. Dieppa, R.K. Hubbard, E. Mas, D. Sotomayor, T.L. Potter, E.M. Steglich, T.C. Strickland, and R.G. Williams. 2013. Hydrology and water quality of a field and riparian buffer adjacent to a mangrove wetland in Jobos Bay Watershed, Puerto Rico. Ecological Engineering **http://dx.doi.org/10.1016/j.ecoleng.2012.09.005**.

3B. Improving Our Ability to Select and Place Conservation Practices On the Landscape for Maximum Effectiveness

Reduction in nutrient export via a new precision conservation toolkit. Individual conservation practices can improve water quality if they are placed in appropriate locations, but conservation at the watershed scale is most effective when suites of practices are placed so that they work in concert to achieve maximum conservation benefits. ARS scientists in Ames, Iowa, have proposed a combination of precision conservation techniques that comprise a flexible framework appropriate for Midwestern landscapes and are applicable to small watersheds of less than 30,000 acres. The framework is based on a set of computerized landscape analyses using newly available, detailed elevation data to identify where different types of conservation practices can be placed to improve water quality most effectively. These analyses help both conservation planners and landowners develop planning alternatives that map how selected suites of conservation practices can be distributed to address key pollutant pathways in both surface and subsurface-drained landscapes. These scenarios provide the flexibility needed for local conservation planning decisions. The framework was described in a recent feature article in the Journal of Soil and Water Conservation—the journal's most downloaded paper in September and October 2013. Tests of this framework are being initiated in Iowa, Indiana, and Minnesota.

Tomer, M.D., S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. Journal of Soil and Water Conservation 68(5):113A-120A.

Models help guide wetland placement in agricultural watersheds to reduce nutrient movement. The wide installation of nutrient removal wetlands in tile-drained watersheds of the Midwest may represent the best opportunity to reduce nitrate loads in the Mississippi River Basin and mitigate Gulf of Mexico hypoxia with a single conservation practice. To implement this approach effectively however, suitable locations to place wetlands must be identified, and

their potential impacts on nutrient load reductions quantified at the watershed scale. ARS scientists in Oxford, Mississippi, and Ames, Iowa, used an aerial laser altimetry survey to develop a detailed topographic map of a Hydrologic Unit Code 12 (HUC-12) (16,000 acre) watershed in Illinois. The scientists applied a conservative set of criteria, modified from a wetlands program in Iowa, to identify 11 sites that could be converted to wetlands with minimal loss of productive cropland, and that could intercept and treat tile drainage from 30 percent of the watershed. A modeling exercise estimated that these wetlands could reduce nitrate loads from the watershed by as much as 16 percent, but load reductions among the wetland locations varied considerably, depending on watershed-to-wetland area ratios, land use in the upslope area, and nitrate loads generated under that land use. These issues will need to be considered by policy makers interested in developing incentives to encourage wetland construction and/or restoration at the watershed scale.

Tomer, M.D., W.G. Crumpton, R.L. Bingner, J.A. Kostel, and D.E. James. 2013. Estimating nitrate load reductions from placing constructed wetlands in a HUC-12 watershed using LiDAR data. Ecological Engineering 56:69-78.

3C. Improving Conservation Practices To Better Protect Water Resources

Wetland restoration. The ultimate goal of wetland restoration is to restore important wetland ecosystem services such as retention of nutrients, water storage, and wildlife habitat. These benefits, however, can be offset by increased greenhouse gas emissions. In support of the Wetlands Component of USDA's Conservation Effects Assessment Project (CEAP) for the Mid-Atlantic Region, ARS scientists in Florence, South Carolina, assessed the impact of wetland loss through conversion to agricultural lands, and wetland restoration, on carbon dioxide and nitrous oxide emissions and associated microbial communities, in three land use types: natural wetlands with native vegetation; wetlands converted to agricultural fields; and restored wetlands. While wetland restoration does appear to have a significant influence on the structure of soil bacterial communities, the restoration process does not appear to exacerbate greenhouse gas emissions.

3D. Maintaining the Effectiveness of Conservation Practices Under Changing Climate and Land Use

Conservation tillage mitigates soil loss under climate change. In Oklahoma, annual precipitation is anticipated to decrease and extreme rainfall events to increase as the climate changes with global warming. Soil erosion under such a climate is expected to increase because of the increased occurrence and intensity of heavy storms. ARS researchers at El Reno, Oklahoma, used computer modeling techniques to evaluate the effectiveness of various tillage and cropping systems in controlling soil erosion under climate change. Results showed that under the same tillage and cropping systems, soil loss will increase in the future despite projected decreases in annual precipitation, primarily due to the increase in heavy storms. However, conservation tillage, especially no-till, should be able to keep soil loss within acceptable levels. Wheat is more effective in reducing soil loss than cotton, soybean, or sorghum. This work provides a scientific base for widespread adoption of conservation tillage to combat soil erosion in regions expected to experience an increase of precipitation intensity (?) under climate change..

Zhang, X.J. 2012. Cropping and tillage systems effects on soil erosion under climate change in Oklahoma. Soil Science Society of America Journal 76(5):1789-1797.

3E. Understanding How Conservation Practices Affect Ecosystem Services

Reducing the export of reactive nitrogen from agricultural lands in the Chesapeake Bay watershed. The wide-spread adoption of no-till crop production practices has significantly reduced soil erosion and associated nutrient loss, but when soil nitrogen is not incorporated through tillage, nitrogen losses due to the volatilization of ammonia from manure can be comparatively high. ARS researchers in University Park, Pennsylvania, evaluated several low-disturbance manure incorporation technologies to determine their capacity to reduce ammonia-based nitrogen losses. Shallow disk injection consistently reduced ammonia emission by more than 90 percent with little disruption of the soil surface. In contrast, manure incorporation using a rolling-tine aerator consistently reduced ammonia losses only when the implement was configured to aggressively mix soil. Extension presentations disseminated these findings to farmers throughout the Chesapeake Bay region, influencing the development by USDA Natural Resources Conservation Service of interim practice standards for manure injection in Pennsylvania and other states in the Chesapeake Bay watershed.

Myers, T., C.J. Dell, and D. Beegle. 2013. Evaluation of ammonia emissions from manure incorporated with different soil aerator configurations. Journal of Soil and Water Conservation 68(4):306-314.

Problem Area 4 – Improving Watershed Management and Ecosystem Services in Agricultural Landscapes

4A. Developing Tools To Improve Hydrologic Assessment and Watershed Management

Agricultural Policy / Environmental eXtender (APEX) model parameterization and calibration. The APEX model was developed to assess a wide variety of agricultural water resource, water quality, and other environmental problems at whole farm, watershed, and landscape scales. To obtain a good match between model results and observed data, the model requires a suite of input parameters whose values must be determined and adjusted. Scientists and researchers who want to use APEX need guidance about the steps of this process. In collaboration with the University of Missouri and others, ARS scientists in Columbia, Missouri, highlighted important parameters and provided guidance on input parameters and how they can be adjusted to obtain results that match measured data. Several case studies were examined—a 35-ha field in north central Missouri, the 5720-ha Clear Creek watershed in central Texas and several catchments at the Greenley research site in north Missouri. Together these case studies provide examples of APEX applications to simulate streamflow, crop yields, and sediment, nutrient and atrazine yields. These results are important to ensure that APEX, a model used to estimate the environmental and productivity impacts of agricultural management practices, is correctly used.

Senaviratne, A., R.P. Udawatta, C. Baffaut, and S.H. Anderson. 2013. Agricultural Policy Environmental eXtender simulation of three adjacent row-crop watersheds in the claypan region. Journal of Environmental Quality 42:726-736.

4B. Improving Watershed Management and Ecosystem Services Through Long-Term Observation and Characterization of Agricultural Watersheds and Landscapes

Model improves erosion prediction while expanding applications. The Water Erosion Prediction Project (WEPP) is a process-based model used to estimate soil erosion and sediment deposition on hill slopes, incorporating climate, water balance, plant growth, runoff routing, and sediment detachment and deposition components. ARS researchers in West Lafayette, Indiana, improved the WEPP model by adding new routines for channel flow routing, water percolation to lower layers (which can be used to estimate watershed baseflow), and tile drainage. The team also conducted a series of sensitivity and uncertainty analyses, and demonstrated how to calibrate and validate the model using measured data. The USDA Natural Resources Conservation Service (NRCS) has requested help from the ARS team to further develop the WEPP model for incorporation into their conservation toolkit. As a result, state and local NRCS offices will have the capability to use the most advanced erosion prediction technology in their conservation planning. To further utilize the spatial capability of this model, the ARS team is cooperating with scientists from the U.S. Forest Service, Washington State University, and the University of Idaho to develop GIS interfaces for the WEPP model to make erosion assessments in the Great Lakes and Lake Tahoe Basins. Geospatial WEPP applications have already been successfully used to assess watershed hydrology and sediment loss in two forested watersheds in West Virginia. The U.S. Forest Service has also been using this technology to more efficiently select remediation practices after wild fires in the western U.S.

Flanagan, D.C., J.R. Frankenberger, and J.C. Ascough II. 2012. WEPP: Model use, calibration and validation. Transactions of the American Society of Agricultural and Biological Engineers 55(4):1463-1477.

Ascough II, J.C., D.C. Flanagan, M.A. Nearing, and B.A. Engel. 2013. Sensitivity and first-order/Monte Carlo uncertainty analysis of the WEPP hillslope erosion model. Transactions of the ASABE 56(2)/437-452.

Dun, S., J. Wu, W.J. Elliot, J.R. Frankenberger, D.C. Flanagan, and D.K. McCool. 2013. Applying online WEPP to assess forest watershed hydrology. Transactions of the ASABE 56(2):581-590.

Flanagan, D.C., J.R. Frankenberger, T.A. Cochrane, C.S. Renschler, and W.J. Elliot. 2013. Geospatial application of the Water Erosion Prediction Project (WEPP) model. Transactions of the ASABE 56(2):591-601.

Extreme precipitation patterns will decrease vegetative productivity. One recurring forecast effect of global climate change is that precipitation patterns will become more extreme, with fewer, larger storms and longer dry spells. ARS scientists in Tucson, Arizona, and their colleagues conducted an investigation into the observed effect of precipitation variability from 2000 to 2009 on 11 different sites within the continental United States. Results showed that for most biomes tested, a more extreme precipitation pattern had a negative effect on vegetation productivity, and on average, resulted in a 20% reduction in rain use efficiency. With predictions of more extreme weather events, forecasts of ecosystem production should consider these non-linear responses to altered extreme precipitation patterns associated with climate change.

Zhang, Y., M.S. Moran, M.A. Nearing, G. Ponce Campos, A. Huete, A.R. Buda, D.D. Bosch, S.A. Gunter, S. Kitchen, W. Mcnab, J.A. Morgan, M. Mcclaran, D. Sutherland Montoya, D.C. Peters, and P.J. Starks. 2013. Extreme precipitation patterns reduced terrestrial ecosystem production across biomass. Journal of Geophysical Research-Biogeosciences 118:148–157.

4C. Maintaining Water Availability in a Changing Global Environment

Sediment budget developed for a small southwestern watershed. Semiarid areas are among the highest sediment producing regions in the world, but sediment budgets that quantify the long-term movement of sediment at the small watershed scale are rare. ARS researchers in Tucson, Arizona, developed a sediment budget for a 43.7 ha, and a nested 3.7 ha semiarid, shrub dominated watershed. The sediment budget is based on hydrologic, geomorphic, erosion, and sediment data collected from 1963 through 2006 on watershed 223 within the USDA, ARS Walnut Gulch Experimental Watershed in southeastern Arizona. Although the channel network is well developed and incising in the steeper reaches of the watershed, hillslopes are the dominant source of sediment, contributing 85% of the overall total sediment yield. Knowledge of the source area of sediment (hillslope or channel) will assist land use managers in both the targeting of new and evaluation of existing conservation practices.

Nichols, M.H., M.S. Nearing, V.O. Polyakov, and J.J. Stone. 2012. A sediment budget for a small semiarid watershed in southeastern Arizona, USA. Geomorphology 180-181: 137-145.

4D. Developing Tools to Improve the Quantification of Hydrologic Processes and Water Budget Parameters in Varying Landscapes and Under Varying Conditions

Early warning index for flash drought. The flash droughts of 2012 in the U.S. Corn Belt were rapid-onset events fueled by below-normal precipitation levels and a lingering heat wave that essentially "baked" moisture reserves from the soil profile. ARS scientists in Beltsville, Maryland, developed a satellite-based drought product called the Evaporative Stress Index (ESI) that provided early warning of the deteriorating crop and soil moisture conditions in 2012, preceding signals of increasing drought severity recorded by the U.S. Drought Monitor and other standard drought indicators by several weeks. The ESI depicts areas of anomalously low water use and availability, derived from measurements of evapotranspiration (ET) generated with thermal infrared satellite imaging systems. Robust early warning of impending drought provides growers additional time to adjust cropping and marketing strategies during the growing season. ARS scientists are also working with researchers at the USDA National Agricultural Statistics Service to establish the utility of using ESI records of seasonal crop stress to improve estimates of at-harvest yield. With minimal reliance on ground-based observations, the ESI shows good potential for monitoring food and water security at the global scale.

Otkin, J.A., M.C. Anderson, C.R. Hain, I.E. Mladenova, J.B. Basara, and M. Svoboda. 2013. Examining rapid onset drought development using the thermal infrared based Evaporative Stress Index. Journal of Hydrometeorology 14:1057-1074.

Anderson, M.C., C.R. Hain, J.A. Otkin, X. Zhan, K.C. Mo, M. Svoboda, B. Wardlow, and A. Pimstein. 2013. An intercomparison of drought indicators based on thermal remote sensing and NLDAS-2 simulations with U.S. Drought Monitor classifications. Journal of Hydrometeorology 14:1035-1056.

Long-term data from an ARS experimental watershed validates NASA satellite-based rainfall estimates. Water is a critical resource in rapidly developing arid and semiarid regions. Accurate rainfall estimates are essential to effective management of agricultural production and associated water resources, but in many parts of the world, rugged terrain limits the deployment of rain gauges, while simultaneously blocking ground-based radar estimates of rainfall. Working

with colleagues from the National Aeronautics and Space Administration (NASA), ARS researchers in Tucson, Arizona, compared rain gauge observations from the densely instrumented ARS Walnut Gulch Experimental Watershed, with rainfall intensity estimates from the Tropical Rainfall Measurement Mission (TRMM) satellite for the period 1999 to 2010. Results showed a very good agreement between the two sets of rainfall rate estimates, an important finding because rainfall is not well measured over large parts of the globe, and the satellite design is the basis for NASA's new Global Precipitation Mission. In addition to underscoring the importance of ARS long-term research sites and the data sets they enable, the validation presages success for the new NASA mission. Among other benefits, the significance of quantifying precipitation worldwide has important implications for improving the world's capacity for food production in light of expected population growth and climatic uncertainty.

Amitai, E., C.L. Unkrich, D.C. Goodrich, E. Habib, and B. Thill. 2012. Assessing satellite-based rainfall estimates in semi-arid watersheds using the USDA-ARS Walnut Gulch gauge network and TRMM-PR. Journal of Hydrometeorology 13:1579-1588.

4E. Understanding the Water Implications of Biofuel Production

Assessing feasibility and sustainability of bioenergy crop production. In collaboration with their university partners, ARS scientists in Temple, Texas, have parameterized the ARS-developed plant growth model, ALMANAC, for representative ecotypes of switchgrass, to evaluate their potential as alternative second-generation bioenergy crops in the eastern and central United States. This allowed them to assess the feasibility and sustainability of biofuel production in these regions in the face of growing energy production demands and climate change. Under both current and future climate change scenarios, switchgrass productivity showed substantial variation both within regions and over time. In particular, the southern U.S. has the highest current biomass production potential, but is predicted to have the largest future decrease in productivity, because temperature is predicted to increase (and precipitation decrease), in this region. If future climate predictions are accurate, biomass energy production associated with switchgrass cultivation in the southern United States is thus not likely to be sustainable. These results help develop a better understanding of the possibility for large-scale biofuel production from perennial grasses in the eastern and central U.S.

Behrman, K.D., J.R. Kiniry, M. Winchell, T.E. Juenger, and T.H. Keitt. 2013. Spatial forecasting of switchgrass productivity under current and future climate change scenarios. Ecological Applications 23(1):73-85.

4F. Downscaling Climate Change Impacts to Improve Water Availability and Watershed Management

Assessing phenological change in China from 1982 to 2006 using Advanced Very High Resolution Radiometer (AVHRR) imagery. China's rapid economic growth can be attributed largely to the policy of opening special economic zones, launched in 1978. The heterogeneous nature of the policy implies spatial variation of the policy's impacts on vegetation growth across the country. Working with Michigan State University scientists, ARS Researchers in Tucson, Arizona, mapped annual vegetation growth across China from 1982 to 2006, based on remote sensing imagery, and quantified the temporal trend at the 8km x 8km pixel scale. The spatial pattern of the historical trend reveals great variation across the country, coincident with several

national policies launched by the government since 1978. Significant decreasing trends were found along the coastal area of the Pacific Ocean and in areas along the Yangtze River, likely due to the opening of economic zones and inland cities, along with associated anthropogenic causes such as rapid urbanization and deforestation. Significant increasing trends detected in Northeast, Northwest and Central China indicate the effect of the 'Three-North Shelter Forest Programme' in these areas, while the significant decreases in the grassland area of Inner Mongolia indicate desertification.

Wei, H., P. Heilman, J. Qi, M.A. Nearing, Z. Gu, and Y. Zhang. 2012. Assessing phenological change in China from 1982 to 2006 using AVHRR imagery. Frontiers of Earth Science 6(3):227–236.