The Agricultural Research Service

Water Availability & Watershed Management National Program

Action Plan 2011-2015

ARS Water Availability and Watershed Management National Program (211) Action Plan FY 2011-2015

This NP 211 Action Plan applies to 45 Project Plans that will begin on or about October 1, 2011. This is the official version that appears on the website, http://www.ars.usda.gov/research/programs/programs.htm.

Vision

Integrated, Effective, and Safe Water Resource Management

Mission

The mission of this National Program is twofold: (1) to conduct fundamental and applied research on the processes that control water availability and quality for the health and economic growth of the American people; and (2) to develop new and improved technologies for managing the Nation's agricultural water resources. These advances in knowledge and technologies will provide producers, action agencies, local communities, and resource advisors with the practices, tools, models, and decision support systems they need to improve water conservation and water use efficiency in agriculture, enhance water quality, protect rural and urban communities from the ravages of droughts and floods, improve agricultural and urban watersheds, and prevent the degradation of riparian areas, wetlands, and stream corridors. The rationale for this program is that water is fundamental to life and is a basic requirement for virtually all of our agricultural, industrial, urban, and recreational activities, as well as the sustained health of the natural environment.

Background

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 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 its water 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 significantly reduced 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.

Goal

The goal of the Water Availability and Watershed Management National Program (211) is to effectively and safely manage water resources while protecting the environment and human and animal health. This goal will be achieved by characterizing potential hazards, developing management practices, strategies and systems to alleviate problems, and providing practices, technologies, and decision support tools for the benefit of customers, stakeholders, partners, and product users. Customers, stakeholders, partners, and users of this research include producers, landowners, consultants, State agencies, Cooperative Extension Service, NRCS, FS, FSA, FAS, ORACBA, EPA, USGS, CDC, NOAA, NASA, BLM, BOR, USACE, NPS, and other action-oriented organizations and centers.

National Program 211 is part of Goal 6, Protect and Enhance the Nation's Natural Resource Base and Environment, of the ARS FY 2006-2011 Strategic Plan (http://www.ars.usda.gov/SP2UserFiles/Place/00000000/ARSStrategicPlan2006-2011.pdf). It also contributes to Goal 1 (Enhance International Competitiveness of American Agriculture) and Goal 4 (Enhance Protection and Safety of the Nation's Agriculture and Food Supply) of these strategic plans.

Approach

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:

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

These problem areas were chosen after receiving input at a planning workshop designed to understand the problems and needs of our customers, stakeholders, and partners, and from other interactions with interested parties.

Cooperative research among ARS units will occur to develop the products and achieve the outcomes identified in this action plan. Cooperators from academia and other agencies will assist in the actual research and in outreach and technology transfer. Product users such as EPA, extension, NRCS, and USGS will work with us to ensure that we provide the information in the most useable formats for their organizations so that expected outcomes are quickly achieved.

Planning Process and Plan Development

The 211 National Program Workshop was held in September 2010 at Chicago, IL. Nearly 200 participants attended this workshop, including producers, commodity and public interest group representatives, scientists from universities, and scientists and administrators from ARS and other Federal and State agencies. The problem areas in this action plan were formulated based on workshop inputs, and inputs from other activities such as USDA and interagency programs, committees, and meetings attended by our scientists and National Program Leaders. Recent reports from the National Academy of Science, National Science and Technology Council, and U.S. General Accounting Office were also considered as this Action Plan was developed.

ARS scientists used the program logic model to identify general research outcomes, specific products associated with these outcomes, and the resources available to develop these products for each of the problem areas in this action plan. ARS scientists at each of the laboratories participating in NP211 and other relevant National Programs will reference this action plan when developing project plans that describe the research they will conduct. Project plans provide detailed information on objectives, anticipated products or information to be generated, the approach that will be used, roles and responsibilities of ARS scientists and their cooperators, and timelines and milestones to measure progress of the research. All project plans are reviewed for scientific quality by an independent panel of experts in the field. ARS scientists will use input from the review panel to revise and improve their planned research.

Other relevant ARS National Programs include Climate Change, Soils, and Emissions (212); Bioenergy (213); Agricultural and Industrial Byproducts (214); Pasture, Forage, and Range Land Systems (215); Agricultural System Competitiveness and Sustainability (216); Crop Protection and Quarantine (304); Crop Production (305); Food Animal Production (101); Aquaculture (106); and Food Safety (animal and plant products) (108).

Problem Area 1 - Effective Water Management in Agriculture

Problem Statement

Rationale. 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 irrigation and drainage systems must be improved to deal with adverse environmental effects and inevitable reductions in water resources available for irrigated agriculture in some areas.

After thermoelectric generation, irrigation is the largest user of freshwater resources, accounting for 40% of water withdrawals overall, and more than 70% in more arid regions such as the western USA. Surface and subsurface water allocation comprises a complex system of competing and interacting claims from agricultural, energy industry, tribal, environmental, and urban interests, which increasingly leaves agriculture with less water, or with lower quality water, for food, feed, fiber, and biofuel production. Irrigated agriculture must respond with solutions that improve water use efficiency and extend water availability through options such as urban treated wastewaters, recycled drainage waters, and other low-quality waters such as from dairy, aquaculture, animal feeding operations, and commodity processing plants. Economic forces are hastening the transfer of water from agricultural to urban areas and the subsequent decrease of irrigated acreage in the West. At the same time, irrigated acreage is increasing in the Southeast, and in the Mississippi Delta regions of Arkansas, Louisiana, Mississippi, and Missouri. Competition for water has caused conflicts in areas where water was typically abundant. In these sub-humid and humid climates, irrigation problems are frequently different from those in more arid climates, requiring new solutions that are not directly transferable from the irrigated West.

In all regions of the country, irrigation and drainage are now directly related to both environmental and public health, as well as the economic viability of the watersheds within which they operate.

The quest for increased water and nutrient use efficiencies, and for water and food security for the nation and the world, requires solutions that improve water management for efficient agricultural production. Improved systems and technologies that automatically monitor crop responses to water and fertilization are needed to increase irrigation, nutrient use efficiencies, and profitability, while reducing the adverse environmental consequences of irrigation and drainage systems. Developing new sensors to measure soil water content and plant responses is integral to developing these technologies. Better decision support systems (DSS) are required to more precisely determine needs for individual fields and crops, and advanced irrigation technologies are needed to use DSS automatically for site-specific management within fields. Current electronic technologies exist that can be used to develop systems that provide continuous site-specific feedback to managers for determining when and how much to irrigate, drain, fertilize and pump. There has been recent, renewed success in providing crop water use values to irrigation managers using the paradigm of a reference evapotranspiration multiplied by a seasonally adjusted crop coefficient (K_c). However, this success has generated demand for new knowledge of K_c for high-value horticultural, alternative, and biofuel crops. Demand is also growing for a K_c approach that transfers well across climatic regions, especially for application in humid climates. Important new work is aimed at developing tools for irrigation scheduling in humid and sub humid regions.

Beyond the scale of single fields, there is a need for improved management and evaluation tools at the farm, irrigation and drainage district, and watershed scales. These include assessment tools for managers and action agencies that encompass a range of problems, from canal and pipe system operation/automation, to methods of evaluating irrigation and drainage project performance and the impact of new technologies and Best Management Practices, to tools to assess the suitability of lower quality waters and needed amendments or other management options for their use, and new or revised irrigation district policies or regulations. Continued development of remote sensing applications will improve irrigation scheme assessments.

Drainage comprises the natural aspects of water moving down slope through soils, swales, streams, and rivers as well as the use of constructed features, including terraces, grassed waterways, and surface and subsurface drainage systems (e.g., ditches and pipes), to manage the water movement on and from the land. Climate change predictions indicating warmer temperatures, more rainfall, and more extreme events for the Midwest add urgency to the need to develop innovative cropping and drainage water management (DWM) systems, technologies and guidelines. Surface and subsurface DWM systems are crucial for economic production and represent the best available technology for reducing offsite water quantity and quality impacts for both rainfed and irrigated agriculture. Contaminants carried in runoff and subsurface drainage from cropland are often the major contributors to nonpoint source water quality problems in streams and other surface water bodies; DWM systems show considerable promise in reducing these pollutant loadings. Where it is not possible to apply DWM systems, alternatives include modified cropping practices, use of cover crops, bioreactors and other in-line treatment or filtration technologies. Diverting runoff and subsurface drainage waters through existing or constructed wetlands may prove effective for pollutant removal.

The decreasing supply of fresh water for irrigation, coupled with the increase of wastewater from urban areas and large livestock facilities, leads to the need for irrigation strategies that work well with wastewaters as well as with saline and otherwise degraded waters not currently used. Safe use of these waters requires new knowledge of the fate, transport, and control of emerging contaminants, pathogens, and potentially toxic elements, as well as assessment of soil salinity and management strategies. Additional information is needed on leaching requirements, as current leaching guidelines appear unrealistically high, serving to discourage the use of brackish waters for irrigation and encourage excessive leaching. Studies are needed to evaluate the long term impacts of degraded water use on soil physical and chemical properties as well as on drainage water quality. Additionally, new crop varieties are needed for production with degraded waters. Varietal improvements and crop selection for tolerance or phytoremediation of degraded soils should include consideration of ion imbalances, toxic elements, and tolerance to salinity, as well as to multiple stresses such as salinity and boron together. Public resistance to the reuse for irrigation of water reclaimed from municipal treatment facilities and livestock operations has increased due to the detection of pharmaceutically active compounds and pathogens at very low levels. Assessments are needed to determine if these constituents are naturally attenuated or accumulate in the environment, and efforts are needed to find methods to attenuate their impacts.

Finally, as irrigation water supplies decline, an important pattern of rotation between irrigated and non-irrigated crops is emerging. Efficient use of the water resource in these cropping systems requires new tillage, irrigation, and crop management tools to reduce runoff and leaching, maximize the effective use of precipitation, and minimize water losses to evaporation. Tools are needed so that managers can evaluate choices among crops, irrigation amounts, or trading water to other users. Increased urban-agricultural water trading leads to the need to quantify the amount of water saved when fields are not irrigated, or are more efficiently irrigated so users receive accurate credit for traded water.

Research Needs. Customer needs were identified during the National Program 211 Workshop held in Chicago in September 2010, and through contacts with producer and commodity organizations, irrigation and drainage industries, water and irrigation districts, water conservation districts, and action agencies at the federal and state levels. The needs of the various stakeholder groups were discussed relative to national and departmental priorities concerning climate change, future biofuel goals, and national food security. Six overall outcomes were identified:

- **1.1: Irrigation Scheduling Technologies for Water Use Efficiency** – Improving the efficiency of water use in production agriculture is necessary for sustaining and expanding food and biofuel production in the face of increasing water demands for non-agricultural uses. Strategies pursued will include more accurate irrigation scheduling based on weather data, plant- and soil-based sensor systems to guide and automate irrigations, deficit irrigation management and irrigated-dryland-rain fed rotations to use scarce water supplies and precipitation more efficiently, site-specific irrigation systems to place water where it is most effective, and integrated climate-crop-economic models to determine profitable and sustainable water use strategies.
- **1.2: Water Productivity at Multiple Scales** – Competing demands for water, including for biofuel production, require knowledge of crop water productivity for decision making on the farm, within irrigation and underground water management districts, for interstate and international water arrangements, and for policy makers and planners at all levels. Strategies will include field-scale measurement of water use efficiency for multiple locations and crops in both irrigated and dryland/rain-fed farming systems, and development of more effective remote sensing tools for determination of regional scale crop water use.
- **1.3: Irrigation Application Methods** – As irrigation application through pressurized irrigation systems has increased to cover 62% of irrigated lands in the nation, water use efficiency has doubled; but in many areas, irrigation is still applied using surface gravity-flow methods, which may be energy and water efficient under some circumstances. Choice and design of appropriate irrigation application systems requires in depth understanding of the complex interactions of application method, cropping system, and the related energy, water and nutrient use efficiencies.
- **1.4: Dryland/Rainfed Water Management** – Water management in dryland and rainfed farming systems is key to sustaining productivity and improving water use efficiency in the face of short and long term climatic stresses. Strategies for improving productivity and sustainability include no-tillage systems, crop selection and rotation, planting geometry and sequences of production that combine dryland/rain fed farming with limited irrigation and grazing systems to maximize precipitation use efficiency.
- **1.5: Drainage Water Management and Control** – The application of surface and subsurface drainage systems has greatly increased the productivity of 120 million acres in both rain fed and irrigated regions of the nation. But increased use of fertilizers and increased variability of precipitation in rain fed regions require new solutions for drainage water management. Strategies to reduce fertilizer and sediment movement from fields to waterways, and to control and store drainage water for use in irrigation, include system design and management tools, water control and automation technologies, bioreactor designs for removing nutrients, and agronomic interventions such as wetland basins and cover crops. Tying these technologies and best management practices to nutrient trading credits will increase the application and sustainability of these practices.
- **1.6: Use of Degraded Waters** – Even as the nation faces increasing water demand for non-agricultural uses and growing urban populations, the availability of degraded waters from municipal, industrial and agricultural sources has increased. Strategies for safe and effective use of degraded waters for agricultural production include development of indicators for emerging contaminants and pathogens, assessment of persistence of these agents in treated waste waters, plant selection and breeding for tolerance to salinity and

specific ions, and irrigation application and scheduling guidelines for sustainable effective use of degraded waters and the nutrients they contain.

Problem Area 1 – Effective Water Management in Agriculture

1.1. Irrigation Scheduling Technologies for Water Use Efficiency			
Inputs/Resources	**Research Activity**	**Outputs/Products**	**Outcomes**
Product 1.1.1. Leader Maricopa, AZ: D. Hunsaker **Product Locations** Bushland, TX; Columbia, MO; Florence, SC; Ft. Collins, CO; Lubbock, TX; Maricopa, AZ; Parlier, CA; Stoneville, MS **Cooperators** R. Allen (U. of IS-Kimberly), J. Chavez (CSU), M. Dukes (UF), Floral and Nursery Research Initiative Project: Nursery Production Technologies for Enhancing Water Quality Protection and Water Conservation, Henggeler (MU-DRC), S. Irmak (UNL), T. Marek (Texas AgriLife Research-Amarillo), NC1186 –Water Management and Quality for Ornamental Crop Production and Health, R. Snyder (UC-Davis)	Field soil water balance and weighing lysimeter studies will determine crop coefficient (Kc) vs. reference evapotranspiration (ETo) relationships and Kc vs. plant property relationships for crops (including bioenergy and horticultural crops) as influenced by irrigation system and management.	1.1.1.1 Relationships between Kc and plant growth and ETo models that are valid across regions and climatic zones (includes horticultural and biofuel crops): Assemble available crop coefficients from various sources and develop uniform presentation format. 1.1.1.2. Alternative methods to compute crop evapotranspiration that are more accurate and transferrable across regions than the current reference Kc-ETo approach	**Short term *** Simpler and more efficient irrigation scheduling based on plant needs result from the development of real-time crop coefficients based on alternative plant measurements. **Long term **** Improved crop water need estimation using new Kc methods supplemented by accurate and reliable approaches that integrate ET energy-balance and cropping systems models. Increased crop water productivity and reductions in nutrient loading in runoff due to increased confidence and adoption of ET-based irrigation scheduling.
Product 1.1.2. Leaders Bushland, TX: S. O'Shaughnessy	Field studies to develop wireless soil water and plant water stress sensors and sensor networks and sensor-based feedback	1.1.2.1. Plant & soil feedback sensor systems and tools for irrigation, nutrient and drainage management (low cost, reliable	**Short term** Sensor systems are available to guide irrigation, fertigation, and drainage systems. An accurate, deep

Product Locations Bushland, TX; Florence, SC; Ft. Collins, CO; Lubbock, TX (203); Maricopa, AZ; Parlier, CA; Stoneville, MS **Cooperators** Acclima, Inc., P. Andrade-Sanchez (UA), Carman (WRID), M. Hebel (S. IL U.), Kluitenberg (KS State U.), H.C. (Lyle) Pringle (Delta Research and Extension Center, MS State U.), K, Holland (Holland Sci.), Tacker (Delta Plastics)	algorithms for monitoring and control of irrigation and nutrient applications and drainage of annual (agronomic) and perennial crops (fruit, nut, landscape).	wireless sensors and algorithms to determine soil water and plant water status and biotic stress)	profiling soil water content sensor is available for irrigation management and water use determination. Soil water sensing technology evaluation aids sensor choice. **Long term** Commercial irrigation-fertigation-drainage systems are automated/guided by wireless sensor systems with resulting improvements in water and nutrient use efficiencies and reductions in environmental impacts. Sensor systems support long-term scientific monitoring of variability and change.
Product 1.1.3. **Leaders** Bushland, TX: S. Evett Ft. Collins CO: L. Ahuja **Product Locations** `Akron, CO (212); Beltsville, MD; Bushland, TX; Ft. Collins, CO; Lubbock, TX; Maricopa, AZ; Oxford, MS, (Jonesboro, AR); Parlier, CA; Weslaco, TX **Cooperators** CA Table Grape Commission, S. Donk, EJ Gallo (N. Dookozlian), N.	Plot, field and watershed scale studies to characterize yield, quality and crop water productivity of annual (agronomic) and perennial crops (e.g., peach, grape) under deficit irrigation that is regulated according to a) crop & soil water stress sensing systems, b) crop growth models based on weather measurements, or c) irrigation supply capacity and timing. Multiple-scale studies to evaluate remote sensing and related measurement techniques and enhance	1.1.3.1. Deficit irrigation management tools for all crops: Irrigation timing strategies, automation & control systems, crop rotations, irrigated-dryland-rain fed rotations, crop growth models of the physical processes affecting crop yield & quality under water deficit conditions; remote sensing-based monitoring of plant stress and water use. 1.1.3.2. Improved crop development & growth models of the biophysical processes affecting crop	**Short term** Water conservation results from the development of deficit irrigation strategies for a range of crops & regions. **Long term** Commercially available plant and soil feedback systems reduce irrigation management time and improve crop water productivity, yield & quality.

Hanson & J. Schneekloth (CSU), G. Hergert (UNL), KS State U. (Aiken, S. Irmak, N. Klocke, F. Lamm, D. Rogers, Schlegel), J. Lohr Vineyards, D. Martin, S. Maas (TX Tech.), J. Owen (OR State U.), Sun Maid Growers, D. Yonts	understanding of the biogeophysical processes regulating ET to improve modeling of water use and plant stress, including over a broad range of land cover types ranging from grassland and/or rangeland to row crops and complex, highly clumped canopies (e.g., orchards, vineyards).	development, yield & quality under water deficit conditions.	
Product 1.1.4. Leaders Florence SC: K. Stone **Product Locations** Bushland, TX; Columbia, MO; Florence, SC; Maricopa, AZ; Stoneville, MS; **Cooperators** W. Bauerle, (CO State U.), Bordovsky (Texas AgriLife-Halfway), M. Hebel (S. IL U.), Holland Sci.; L. Johnson (NASA-Ames); Lamm (KS State U.), NC1186 – Water Management & Quality for Ornamental Crop Production and Health Valmont Industries Inc., U. of AZ (Tucson & Maricopa), T. Yeager (U. of FL), J. Owen (OR State U.),	Field and plot studies of automation and control systems for site-specific irrigation and nutrient application systems, integrating sensor systems from Product 1.1.2 into decision support systems developed in Product 1.1.3 while evaluating spatial soil water status and plant stress and developing use of crop growth models for spatial irrigation.	1.1.4.1. Site specific irrigation (SSI) management tools (devices & algorithms to detect site-specific biotic and abiotic stresses, tied to irrigation control & scheduling systems for site-specific nutrient & water applications)	**Short term** Tools for site-specific irrigation and nutrient application improve crop production and reduce irrigation water use **Long term** Integrated water and nutrient management decision support systems are commercially available that can be specifically tailored for site-specific irrigation and nutrient management including plant and soil feedback systems. Such systems reduce irrigation and nutrient management time and improve crop water and nutrient productivity.
Product 1.1.5. Leader Lubbock,TX: Mauget **Product Locations** Florence, SC; Lubbock, TX; St. Paul, MN	Analysis of historical data to identify recent climate trends. Evaluation of long term weather trends integrated with irrigation scheduling for arid to humid	1.1.5.1. Integrated crop management and irrigation scheduling tool based on climatological information, climate trends and forecasts, crop modeling, and	**Short term** Improved models and methods for irrigation scheduling and crop management use climatological information, including short term forecasts.

Cooperators J. Johnson (TTU), Nemani (NASA-Ames), Staggenborg (KS State U.),	regions. Economic analysis to identify optimal management strategies for a range of production and climate scenarios	economic models. **Product Users****** Valmont Industries; PivoTrac Monitoring; Nelson Irrigation Corp; Texas State Soil & Water Conservation Board; Growers; Irrigation consultants; Water planners; Irrigation/water districts; NRCS; crop consultants, crop commodity organizations, Monsanto, DuPont, extension specialists	**Long term** Decision support tools using climatological information are used to manage crop choices and identify optimal irrigation strategies. Future irrigation and/or crop choices are projected based on climate trends over key growing regions.
1.2. Water Productivity at Multiple Scales			
Product 1.2.1. Leader Temple, TX: J. Kiniry **Product Locations** Bushland, TX; Columbia, MO; Dawson, GA; Florence, SC; Ft. Collins, CO; Kimberly, ID; Maricopa, AZ; St. Paul, MN; Stoneville, MS; Temple, TX **Cooperators** Aiken, Holman, Klocke, Lamm, Schlegel (KS State U.), Auld, Maas, Zartman (TX Tech.), Bean, Bordovsky, Marek, Park, Rudd, Rush, Trostle, Xu, Xue (Texas AgriLife), Blaser, Stewart (WTAMU), CA Dept. of Water Resources, CA Table Grape Comm., J. Davenport (WA State U.), J.	Field studies with various crops to develop crop production functions. Field studies to determine water productivity & sustainability of rangeland and cultivated biofuel crops in various climatic regions. Large-plot studies to develop water-yield relationship for sprinkler irrigated rice. Summarize new and existing data from field and plot studies on agronomic crops, horticultural crops and biofuels. Establish water-yield relationships for corn-kura companion crop systems	1.2.1.1. Crop water productivity and water-yield-quality relationships for agronomic, biofuel and horticultural crops 1.2.1.2. A database of water use efficiencies and requirements for agronomic, horticultural and biofuel crops.	**Short term** A database of water use efficiencies and requirements for agronomic, horticultural and biofuel crops is used by economists, planners and policy makers to estimate water productivity for different cropping and biofuel production scenarios. **Long term** Decision making tools for agronomic, biofuel and horticultural crop selection & production are available to and used by economists, producers, and district, regional, state and federal managers and policy makers to address water productivity, harvest quality and yield goals in the contexts of profitability and

Deiner (Red Rock Ranch), EJ Gallo, Henggeler, Thompson, Stevens (MU-DRC), J Lohr Vineyards, M. Nakahata (HC&S, Maui), Paramount Farming (E, Wilkins), Strawberry Comm., Sun Maid Growers, G. Uehara (U. of HI), P. Waller & M. Ottman (U. of AZ),			resource sustainability.
Product 1.2.2. Leader Beltsville, MD: W. Kustas Maricopa, AZ: A. French **Product Locations** Ames, IA (212) Beltsville, MD; Bushland, TX; Maricopa, AZ; Weslaco, TX **Cooperators** R. Allen (U. of ID-Kimberly), J. Chavez (CO State U.), C. Hain (NOAA-Silver Spring), JPL, Marek & Porter (TX AgriLife), J. Mecilkalski (U. of AL), NASA-Ames & Goddard, Charles Sturt U. (New South Wales, AU), Vara (KS State U.)	Plot, field and regional scale studies to sense and measure ET and to test spatial models of ET that are based on data from satellite and airborne remote sensing platforms, including investigating techniques for downscaling regional ET estimates to field and ground observation scale and upscaling single point and network in-situ observations to field and watershed scales.	1.2.2.1. Remote sensing tools for routine delivery of ET information at field to regional scale. 1.2.2.2. Robust methods for estimating ET at various spatial and temporal scales. **Product Users****** DOE, NRCS, NASA, NOAA, USGS, BLM, Ground and surface water conservation districts and authorities, Action agencies, Consultants	**Short term** Reliable algorithms are available to use remote sensing data in ET estimation at various spatial resolutions. **Long term** Routine estimates of ET at multiple scales using aircraft and satellite remote sensing platforms are made available for water resource research and operational applications for water management.
1.3. Irrigation Application Methods			
Product 1.3.1. Leader Bushland, TX: P. Colaizzi **Product Locations** Bushland, TX; Columbia, MO; Dawson, GA; Maricopa, AZ; Oxford, MS	Field studies of irrigation application system effects on whole-field water use and nutrient use efficiencies. Studies comparing different production systems for field crops (e.g., traditional flood,	1.3.1.1. Irrigation application method comparisons in terms of water and energy use, and water and nutrient use efficiencies 1.3.1.2. Tool to optimize subsurface drip irrigation lateral	**Short term** Assessments of crop productivity as affected by choice of sprinkler or drip irrigation systems are used by farmers, action agencies and planners to affect system design and incentive decisions.

(Jonesboro, AR) **Cooperators** Bordovsky & Porter (TX AgriLife), CA Poly. U., Lamm, Martin, O'Brien, Stone (KS State U.), Stevens (MU-DRC), UT State U., Calvin Perry (Univ. GA)	0 grade, sprinkler). Includes comparison of flood and sprinkler irrigation of field crops, and tools for evaluating, designing, comparing, choosing and improving water application methods in terms of water, nutrient and energy use and tied to the NRCS soils database	spacing and depth	A tool to optimize subsurface drip irrigation lateral spacing and depth is used by farmers, action agencies and vendors to design and decide on incentives for drip irrigation systems. **Long term** Tools for evaluating and predicting the crop water and nutrient productivity and energy use of water application methods (sprinkler, drip, surface), with links to the NRCS soils database are used by growers and NRCS Tools help producers select the most profitable and sustainable irrigation system given the constraints of water availability, soils, energy costs and changing climate, and using field measurements combined with the NRCS soils database.
Product 1.3.2. Leader Kimberly, ID: D. Bjorneberg **Product Locations** Kimberly, ID; Maricopa, AZ **Cooperators** Prestwich & Robinson (NRCS), Nelson Irrigation Corp.	Develop, enhance and evaluate models and design aids to analyze irrigation system performance, including runoff, infiltration and soil erosion. Perform field and plot studies to test models and design aids for surface sprinkler and drip irrigation methods.	1.3.2.1. Software tools and design aids linked to NRCS soils database, to analyze irrigation system impacts on soil, water and energy resources. **Product Users****** DOE, USDA-FS, Growers, consultants, Ground and surface water conservation districts and NRCS.	**Short term** Decision tools are used to select irrigation methods, evaluate system performance, and determine management practice effects on soil and water resources at the field and farm scales. **Long term** Decision aids are used for comparing effects of irrigation methods

			and management on water, nutrient and energy efficiency at the field and watershed scales.
1.4. Dryland/Rainfed Water Management			
Product 1.4.1. Leader Bushland, TX: Schwartz, **Product Locations** Akron, CO (216,204, 212); Bushland, TX; Dawson, GA; Florence, SC; Lubbock, TX; Oxford, MS (Jonesboro, AR); Pendleton, OR (202); Weslaco, TX **Cooperators** Blanco & Schlegel (KS State U.), Bureau of Economic Geology (U. of TX-Austin), Dept. of Agronomy and Dept. of Soil and Crop Sciences (TX AgriLife), Southwest Research-Extension Center - Tribune Unit (KS State U.)	Field studies of tillage and compaction effects on timing, distribution within the soil profile, and amount of water available for crop germination and growth resulting in best management practices to achieve yield and water use efficiency goals. Studies addressing impact and remediation of soil compaction in rainfed cotton.	1.4.1.1. Tillage/no-tillage practice effects on water availability, plant establishment, yield and water productivity. 1.4.1.2. Cropping, tillage, and water management to preserve groundwater and recharge aquifers.	**Short term** Decreased evaporative losses and improved crop production with limited precipitation or irrigation. **Long term** Increased water availability to crops and maximized yield under limited precipitation or irrigation.
Product 1.4.2. Leaders Bushland, TX: J. Tolk Ft. Collins, CO: T. Green **Product Locations** Akron, CO (204, 212, 216) Bushland, TX; Dawson, GA; Ft. Collins, CO; Kimberly, ID; Lubbock, TX	Alternative crop rotation and planting effects on water use and production will be measured at field stations and simulated using agricultural systems models. Alternative management practice effects on crop yield and WUE will be simulated for projected and historical climates.	1.4.2.1. Yield and overall water use efficiency relationships with soil water availability as affected by crop selection, rotation and geometry, and sequences of irrigated-dryland-rainfed-grazing production 1.4.2.2. Guide to crop rotation and planting geometry effects on yield and water use	**Short term** Expanded databases of soil water availability as affected by crop and soil are available/used for dryland crop selection and irrigation scheduling under different climate regimes. **Long term** Profitability maximized under water deficits because tools are available to allocate

Cooperators CO State U., Dept. of Agronomy (KS State U.-Staggenborg), Klocke (KS State U.-Garden City), Schlegel & Haag (Southwest Research-Extension Center - Tribune Unit, KS State U.), TX AgriLife		efficiency **Product Users****** NRCS, extension, producers	water to crop sequences. Effective use of available soil water and precipitation due to coupling of planting geometry and crop rotation choices.
1.5. Drainage Water Management and Control			
Product 1.5.1. Leader Columbus, OH: B. Allred **Product Locations** Ames, IA; Columbus, OH; Orono, ME (E. Wareham, MA); Oxford, MS (Jonesboro, AR); Parlier, CA; **Cooperators** ASABE, Brown (OH State U.), Cooke (U. of IL), C. Demoranville (U. of MA Cranberry Experiment Station, E. Wareham), M. Helmers (IA State U.), Hu & Luk (North American Hoganas), Kladivko (Purdue U.), NRCS Technical Center, Panoche Water and Drainage District (D. Falaschi), Skaggs & Yousef (NC State U.), Strock & Sands (U. of MN), U. of MS, US BOR Technical Center, USGA, West Lafayette, IN	Watershed and field scale studies to: evaluate subsurface drainage system design, management and operation strategies; quantify subsurface drainage economic and environmental benefits; and develop/assess new technologies for mapping drainage pipes.	1.5.1.1. Subsurface and surface drainage system design and management guidelines for rainfed and irrigated conditions: (Design, management, operation, and mapping tools/guidelines to provide environmental benefits, while sustaining soil quality and crop production.), including tail water capture and reuse, removal of irrigation flood waters from rice, croplands, and cranberry fields, and nursery, floricultural and turf systems 1.5.1.2. Assessment and development of draft drainage water management tools/guidelines based on compilation of existing research data. 1.5.1.3. Guidelines for minimizing downstream water quality and water quantity impacts of drainage management.	**Short term** Tools and guidelines are used by producers, drainage managers and industry to improve drainage water management **Long term** Updates of existing ASABE, BOR and NRCS standards for design, operation, and management of subsurface and surface drainage water management systems,, including drainage water quality impacts on reuse for irrigation, are accepted by users and industry DWM tools/guidelines are refined and finalized based on up-to-date research results so as to enhance DWM practices for environmental and economic benefit.
Product 1.5.2. Leader Ames, IA: D. Jaynes	Plot, field, and watershed scale	1.5.2.1. Improved scientific knowledge of	**Short term** Quantifiable data is

Product Locations Ames, IA; Columbia, MO; Columbus, OH; Ft. Pierce, FL; St. Paul, MN; University Park, PA; W. Lafayette, IN **Cooperators** ADMC, ADMSTF, Brown (OH State U.), Cooke (U. of IL), Environmental Defense Fund, M. Helmers (IA State U.), Hu & Luk (North American Hoganas), IA Soybean Assoc., Kladivko (Purdue U.), Midwest Cover Crops Council, NRCS, USEPA, State Conservation Agencies in IA and OH, Strock & Sands (U. of MN), Western Lake Erie Basin Partnership	research to quantify the nutrient loss reduction potential of new and emerging management practices and their associated agronomic benefits. Modeling of the management practices to develop more robust estimates of their efficacy and cost/benefits across the humid and sub-humid regions of the USA covering a range of climatic conditions. Field and watershed scale research to quantify the impacts of drainage management practices on fate and transport of pathogens and pharmaceuticals	processes impacting pollutant transport, transformation, and losses within artificially drained agricultural settings leading to: a) Innovative management practices for reducing pollutant (nutrient, pesticide, sediment, pathogen, pharmaceutical) losses from artificially drained lands and horticultural operations in the humid and sub-humid USA; b) Development of bioreactor design and management criteria for water treatment and regional potential for N removal; c) Design recommendations for surface inlets and wetland basins; d) Cropping system management criteria including flood-tolerant crop varieties, soil amendments, and cover crops for nutrient capture; e) Design criteria for treatment filter media; BMP for controlled release N fertilizer used on furrow irrigated cotton versus chemigation; f) Improved practices to reduce N losses from large dairies with subsurface drainage. 1.5.2.2. Improved understanding of fate and transport of fertilizer components for micronutrient in horticulture and biotic	available for decision making regarding the potential of denitrification bioreactors. Guidelines are used for proper sizing, maintenance, and operation of bioreactors, surface inlets, and wetland basins. Producers and state and federal action agencies use flood-tolerant crop varieties and fall-planted cover crops recommendations to reduce risk and assess water quality and agronomic benefits and costs, especially across the Midwest. Cost benefit values for the use of cover crops to remove nutrients in U.S. waters lead to wider grower and regulatory acceptance Development of guidelines for design and operation of treatment systems capable of removing nutrients and pesticides from waters released by both small- and large scale subsurface drainage systems. Improvement of computer models used to simulate nitrate transport through the soil profile.

		and abiotic impacts.	**Long term** Interim Conservation Practice Standard #747 "Denitrifying Bioreactors" revised jointly with NRCS. Midwest farm programs such as EQIP include sound recommendations for integrating cover crops. A revised NRCS state Conservation Practice Standard #340 "Cover Crops" is available. Productivity will increase on intermittently wet soils, supporting food security. Widespread reduction in the amounts of nutrients and pesticides released by subsurface drainage systems. Release of flood-tolerant soybean cultivars suitable for the Midwest Increased productivity on intermittently wet soils.
Product 1.5.3. Leader Columbus, OH: N. Fausey **Product Locations** Ames, IA; Columbia, MO; Columbus, OH; Orono, ME (E. Wareham, MA); Oxford, MS (Jonesboro, AR);	Field studies of effects of drainage management and treatment effects on nutrient loss, nutrient use efficiency and crop productivity; and regional assessments of drainage extent and intensity. Geographic and process	1.5.3.1. Technology and protocols developed to validate nutrient trading credits for drainage water management and treatment technologies. Regional assessment of drainage extent, intensity, and impact on agricultural production and water quality.	**Short term** Monitoring tools and remote sensing technologies adapted to accurately quantify drainage flow and water quality. **Long term** Nutrient trading markets provide an additional source of

<table>
<tr><td>Parlier, CA;

Cooperators
AFT, Brown (OH State U.), Environmental Defense Fund, EPRI, Florence, SC,NRCS, USEPA, USGS, West Lafayette, IN</td><td>modeling to evaluate potential nutrient removal due to water management in artificially drained regions.</td><td>**Product Users******
American Sugar Cane League, NRCS, EPA, USDA/Office of Environmental Markets, USGS, EPRI, AFT, Western Lake Erie Basin Partnership; Irrigation and Drainage Districts, Bureau of Reclamation</td><td>revenue for land owners.</td></tr>
<tr><td colspan="4">**1.6. Use of Degraded Waters**</td></tr>
<tr><td>**Product 1.6.1.**
Leaders
Maricopa, AZ: C. Williams
Riverside, CA: S. Yates

Product Locations
Kimberly, ID;
Maricopa, AZ;
Riverside, CA

Cooperators
City of Flagstaff, AZ, City of Maricopa, AZ, D. Davis (Tulare Lake Drainage District), J. Deiner (Red Rock Ranch), Global Water, Town of Gilbert, AZ, WaterReuse AZ</td><td>Laboratory and small plot studies of emerging contaminants and pathogens, including:
a) Field and laboratory studies to determine both compounds and organisms that indicate past or current application of treated municipal waste water.
b) Field and laboratory studies to determine the environmental persistence of compounds and organisms found in treated municipal waste water.
c) Field and laboratory studies exploring the co-occurrence of antibiotics and specific antibiotic resistance in organisms.</td><td>1.6.1.1. Identification of indicators for emerging contaminants and pathogens in waste waters and soils: Assessment of the persistence and effects of emerging contaminants and pathogens from treated waste water in the environment.

1.6.1.2. Develop methods/concepts on efficient use of natural resources and protection of environmental health</td><td>**Short term**
Major problems are identified associated with excess salts, toxic trace elements, organic pollutants or pathogens that degrade soil/water productivity/quality in current agronomic systems

Long term
Safe application of waste waters.</td></tr>
<tr><td>**Product 1.6.2.**
Leaders
Parlier, CA: G. Banuelos
Riverside, CA: C. Grieve

Product Locations
Parlier, CA;
Riverside, CA</td><td>Field and plot studies of :
a) Crop production and plant response with use of degraded waters;

b) Effectiveness of selected plant species for use in phytoremediation;

c) Identification of</td><td>1.6.2.1. Plant selection & breeding for salt tolerance and toxic ions: Select priority crops, evaluate genetic variability, develop breeding program and identify viable plant products from alternative crops</td><td>**Short term**
Selected plant species suitable for irrigation with degraded and saline waters and for phytoremediation & phytomanagement.

Long term
Guide is developed and used for the selection of plant species suitable</td></tr>
</table>

Cooperators J. Diener (Red Rock Ranch), J. Faria (CA Dept. of Water Resources)	genes related to salt tolerance and toxic ion uptake in various salt sensitive species; d) Crop breeding to develop new varieties that over-express genes for salt or specific ion tolerance.	**Product users:** So. CA Metropolitan Water District; US Golf Assoc.; CA Strawberry Commission; J. Lohr, EJ Gallo, CA Wine and Grape Instit., Lambert, UC Davis	for use with saline and degraded waters on new and specialty crops, biofuel production and phytoremediation. New salt tolerant varieties of sensitive crops expand options for using degraded water.
Product 1.6.3. **Leaders** Parlier, CA: J. Ayars Riverside, CA: D. Suarez **Product Locations** Ft. Pierce, Fl; Maricopa, AZ; Parlier, CA; Riverside, CA; St. Paul, MN **Cooperators** Casey (TX AgriLife), City of Maricopa, AZ, DeOtte (W. TX A&M U.), Floral and Nursery Research Initiative, Town of Gilbert, AZ, U. of FL, WaterReuse AZ	Summarize existing data and compile literature search in use of degraded water in production of agronomic and biofuels. Conduct laboratory, small plot, and field experiments on salinity and toxic element management including field assessment technologies and impact of different qualities of degraded water on soil physical properties and soluble ion composition applicable to plant uptake. Multiscale studies to evaluate improve and develop integrated decision support tools.	1.6.3.1. Guidelines for irrigation application method and management/scheduling for degraded and reused waters including nutrient content (e.g. water from CAFOs, municipal sewage systems, industrial sources). 1.6.3.2. Guidelines for water quality criteria models and management practices for irrigation with degraded waters, including salinity assessment, leaching requirements and toxic elements, **Product Users** NRCS, EPA, USGS, Irrigation Association, Friant Water Authority, Town of Gilbert, AZ, City of Maricopa, AZ, WaterReuse Arizona, Global Water, City of Flagstaff, AZ	**Short term** Management guides/models for salinity assessment and leaching requirements improve irrigation methods using saline water and waters containing potential toxic ions. Existing practices for management and use of degraded water are compiled and used to reduce risk. Leaching recommendations for recycled/degraded water are revised and used by growers to reduce nutrient inputs, improve yield and reduce risk. **Long term** Guidelines exist for irrigation method and management BMPs that are related to irrigation water salinity, nutrient content, potential toxic ions, and impact of degraded waters on soil physical properties. Manuals/models on use of poor quality water

			for irrigation of agricultural crops is updated to include current concepts and irrigation methodologies

* The short-term outcomes will be accomplished in the next five years.
** The long-term outcomes will not be fully accomplished in five years given current personnel and physical resources, but significant progress will be made.
*** These scientists are conducting research primarily in the ARS National Program numbered in parentheses.
**** Product users are for products shown in each subproblem area.

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

Problem Statement

Rationale. 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.

Pathogens, nutrients, and sediment, and associated processes like turbidity and organic enrichment, are among the top five causes of impairments for 303(d) listed waters, accounting for nearly half of the Nation's water quality concerns. Sediment generated by soil erosion can have costly impacts on downstream channel habitat and water quality, and reduce reservoir capacity. Erosion of embankments and levees can cause severe flooding and loss of life, while a large number of legacy dams in agricultural watersheds are in need of either rehabilitation or removal. Excess nutrients can accelerate the eutrophication of fresh and marine waters, causing shifts in species composition, noxious algal blooms, and hypoxia (i.e., oxygen depletion). High nitrate levels in drinking water are a human health concern in many parts of the U.S and the world. From point generation to land application, livestock manures are a concern, due both to the nutrient content of manure as well it's potential to harbor pathogens and other compounds (e.g., pharmaceuticals, endocrine disrupting compounds) that can degrade water quality. Both pesticides applied to agricultural fields (e.g., insecticides, herbicides, fungicides) and pharmaceuticals used in livestock production (e.g., antibiotics and hormones) can move from their point of use into surface and ground waters, raising concerns about potential impacts on terrestrial and aquatic ecosystems as well as human health. To fully evaluate these risks, we need to know the sources, transport behavior, fate, and biological impacts of these agrochemicals, at different concentrations and in different combinations in the environment. To better design and refine control practices, new scientific information is needed that clearly delineates how agricultural contaminants move and are transformed within the environment.

Research Needs. Improved ability to predict and manage the sources, transport, and transformation of contaminants must be based on a more thorough understanding of controlling processes. Effective and reliable control strategies and technologies can only be advanced through the development, collection, and application of scientific knowledge of the fate and transport of sediment, nutrients, pesticides, pharmaceuticals, and pathogens. This is critical to continued science-based decision making for total maximum daily loads (TMDLs), establishing nutrient criteria, and watershed management strategies, as well as to determine the site-specific performance of remedial management practices.

Critical needs in erosion research include predicting both the detachment of soil particles and soil materials used to construct embankments, in response to alternative applied stresses. The size distribution and composition of sediment detached by sheet, rill, irrigation-induced, and gully erosion, and changes in sediment size and composition that occur during transport within agricultural fields, as well as through ditches, wetlands, lakes, and streams, remain poorly understood. Uncertainty about the location, size, and expression of ephemeral gullies in cropped fields confounds both the accurate prediction of erosion as well as conservation planning. Research is also needed to quantify the role of climate, soil, crop type, and farm and range management, on the generation, movement, persistence, and cycling of water-borne contaminants as well as their potential ecological impacts. Both new and existing knowledge must be synthesized and made available to scientists, producers, and action agency personnel so they can better understand the linkages between soil, climate, farming, and rangeland practices on water contamination and ecosystem services. This knowledge needs to be formulated into fact sheets, guidelines, and mathematical algorithms incorporated into new or existing computer models, to improve the management of our natural resources and reduce the impact of agriculture on water quality degradation. The application of this knowledge to targeting of conservation practices and assessment of their impacts at larger scales is described in Components 3 and 4 of this Action Plan.

Topics in this problem area include:

- **2.1. Field scale processes controlling contaminant fate and transport**
- **2.2. Quantify and predict in-stream processes**
- **2.3. Ecological response to improved water quality**
- **2.4. Development and testing of cost-effective control measures for agriculture, urban, and turf systems**

Problem Area 2: Erosion, Sedimentation and Water Quality Protection

2.1. Field scale processes controlling contaminant fate and transport			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 2.1.1 Leaders Oxford, MS: G. Wilson, R. Bingner **Product Locations** Oxford, MS; West Lafayette, IN **Cooperators** NRCS, S.N. Prasad (ret.), U. of MS	Field measurements of soil properties associated with ephemeral gullies, along with detailed topographic surveys, under a variety of climate and management conditions. Lab and field studies to quantify the interactions of surface and subsurface hydrology, soil properties, topography, and management practices on ephemeral gully development	2.1.1.1 Technology to enable the quantification of ephemeral and edge of field gully erosion and sediment deposition. 2.1.1.2 Data bases of soil physical, chemical, biological, and hydraulic properties, topography, and management practices, to enable the identification of ephemeral gully location and erosion on landscapes. 2.1.1.3 Improved data bases for critical surface and subsurface flow processes associated with gully erosion. 2.1.1.4 Acoustic and geophysical methods for vadose zone characterization and surface-water-to-ground-water processes. 2.1.1.5 Analytically based predictive relationships for subsurface flow relative to in- and exfiltration processes. 2.1.1.6 Improved and integrated decision support tools to predict gully formation and migration using	**Short term*** Erosion from agricultural fields and landscapes is reduced due to more accurate identification of ephemeral gully location, and improved understanding of surface and subsurface processes causing ephemeral gully erosion. **Long term**** Reduced erosion improves soil fertility and agricultural productivity. Improved management of the fate and transport of contaminants because the incorporation of spatially-delineated surface and subsurface geophysical data in the geotechnical and hydrological modeling of surface erosion, and surface water-ground water interaction, increases the accuracy of watershed hydrology assessment.

		detailed GIS soil, management, and topographic layers.	
Product 2.1.2 Leaders Tucson, AZ: M. Nearing, J. Stone **Product Locations** Reno, NV (215); Tucson, AZ **Cooperators** NRCS, USFS	Rainfall simulation experiments to quantify flow hydraulics and sediment transport relationships. ^{137}Cs studies to measure decadal-scale erosion rates on state and transition models.	2.1.2 Databases and improved measurement techniques for overland flow erosion and sediment transport on rangelands.	**Short term** Improved conservation planning and impact assessment of erosion on rangelands because the processes that control splash, sheet and concentrated erosion are better quantified. **Long term** Rangeland erosion is significantly reduced.
Product 2.1.3 Leader Oxford, MS: R. Wells, **Product Locations** Maricopa, AZ; Oxford, MS; Stillwater, OK; West Lafayette, IN **Cooperators** NRCS, OK State U., Purdue U., WA State U.	Cohesive and freeze/thaw effects on soil erodibility will be assessed through impinging jet, furrow, flume, and other erodibility tests. Effects of management and conservation practices will be assessed through field and laboratory assessment utilizing erodibility tests. Lab and field studies to quantify landscape processes and attributes affecting soil erodibility.	2.1.3.1 Technologies to assess and predict the erodibility of soils and soil materials. 2.1.3.2 Quantification of the effects of soil properties that control resistance of cohesive soils to detachment by hydraulic forces. 2.1.3.3 A predictive tool that describes the effects of freeze/thaw on soil erodibility.	**Short term** Better erosion estimates and control measures enabled by improved ability to predict and measure the resistance of soil to detachment by hydraulic forces, and the validation and reduced uncertainty of testing techniques and analytical procedures for predicting erodibility of cohesive soils. **Long term** Improved water management at field and watershed scales due to more accurate estimates of erosion rates and a better understanding of the role of management practices on sediment-load reductions.

Product 2.1.4 **Leaders:** Columbia, MO: R. Lerch University Park, PA: P. Kleinman **Product Locations** Ames, IA; Beltsville, MD; Columbia, MO; Columbus, OH; Kimberly, ID; Oxford, MS; St. Paul MN; Temple, TX; Tifton, GA; University Park, PA; W. Lafayette, IN **Cooperators** U. of MO, other Land Grant Institutions, NIFA	Field studies to quantify the effects of management practices on runoff of pesticides from turf. Field studies evaluating the fate and transport of nutrients, pathogens and emerging contaminants in drainage systems (tile and open ditch). Field studies to improve targeting of remedial practices by elucidating pathways of nutrient and emerging contaminant transport from field to stream. Lab studies to quantify retention and transformation of new low-application rate herbicides to characterize their potential offsite transport to water bodies. Lab studies to quantify retention and transformation of 'aged' or bound pesticide and pharmaceutical residues Determine effect of antibiotic persistence on pathogen survival in soil. Assess water quality impacts of in-house windrow composting of poultry litter. Conduct studies to	2.1.4.1 Improved knowledge of dissolved phase contaminant delivery processes from agriculture, urban, and turf systems. 2.1.4.2 Improved knowledge of the processes that control the retention, transformation, and transport of contaminants (nutrients, pesticides, metals, pharmaceuticals, and pathogens) and management applications that demonstrably reduce their off-site transport from agricultural, turf, and urban land uses. 2.1.4.3 Data sets describing dominant loss pathways (e.g., degradation, hydrologic transport, and volatilization) for dissolved-phase contaminants derived from agricultural, turf, and urban land uses.	**Short term** Improved understanding of the processes by which field-scale hydrology and management practices impact the dissolved-phase transport of contaminants leads to improved water quality through better management. Improved water quality due to improved integration and understanding of the fate and transport of contaminants from agriculture, turf, and urban land uses. Better water quality management due to improved ability to predict the impact of management practices on contaminant losses in different farming systems. **Long term** Improved surface and ground water quality, and aquatic ecosystem services, due to improved ability to predict the impact of management practices on the movement of chemical contaminants and pathogens from different land uses. Nutrient levels in ground and surface waters significantly reduced.

	enhance SWAT model representation of metals transport in the environment. Process level research to quantify chemical transport from soils and sediments to water. Field studies to determine how redistribution of soil through past erosion and deposition has altered distributions of carbon and nutrients within fields affecting nutrient losses from runoff, tile drains and shallow groundwater flow.		
2.2. Quantify and predict in-stream processes.			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 2.2.1 Leader Oxford, MS: R. Kuhnle **Product Locations** Ames, IA; El Reno, OK; Oxford, MS; Tucson, AZ; West Lafayette, IN **Cooperators** ARS-Ft. Collins, CO, ARS-Manhattan, KS, BLM, EPA, NRCS, U. of MS, U. of Pittsburgh, USACOE, USBR, USFS, USGS	Laboratory and field studies of initiation, erosion, transport, and deposition of aggregated and non-cohesive sediment in channels. Study reservoir sedimentation rates and relate to erosion control watershed management practices. Assemble historic data to quantify the spatial distribution of stock tanks coupled with and compared to field measurements to quantify their long term impact on rangeland sediment transfers. Development and	2.2.1.1 Integrated technologies for predicting total stream system sediment loads by size fraction, aggregated sediment transformation, geomorphic aspects of stream evolution and channel erosion as affected by riparian zone management, reservoir and sedimentation and dam removal impacts on sediment loads and stream morphology in agricultural and rangeland watersheds. 2.2.1.2 Integrated ARS and NCCHE erosion and sediment transport models to allow easier selection and linkage of appropriate models	**Short term** Better understanding of erosion because effective sizes of sediments derived from cohesive soil sources would be documented in field channels. **Long term** Improved ability to quantify landscape scale erosion and evaluate changes in storage of aging reservoirs. Improved and tested process-based erosion models in field and watershed scales using spatially and temporally distributed erosion/sediment data and derived sediment delivery ratios.

	maintenance of process-based water erosion prediction technology Development of process-based wind and water erosion prediction technologies for use at the field, farm and watershed scales Link ARS and NCCHE Erosion and Sediment Transport Models including RUSLE2, AnnAGNPS, CONCEPTS, CCHE1D, and CCHE2D with a common internet-based GIS interface and database management system. Development and deployment of acoustic tools and techniques amenable to autonomous operation to monitor sediment movement at remote locations. Sampling and analyzing activities of ^{137}Cs, ^{210}Pb, ^{226}Ra, ^{7}Be; identifying sediment sources and deriving spatially distributed erosion data.	to answer questions at field, farm, and watershed scales. 2.2.1.3 Surrogate sediment monitoring tools and measurement techniques. 2.2.1.4 Maps of soil erosion redistribution in a watershed and relative contributions of reservoir sediment from uplands vs. channels.	
Product 2.2.2 Leaders Ames, IA: T. Moorman West Lafayette, IN: D. Smith **Product Locations** Ames, IA; St. Paul, MN;	Watershed studies to quantify role of in-stream processes on the fate of nutrients, pesticides and emerging contaminants contributed from upstream sources.	2.2.2.1 Improved knowledge of in-stream processes that govern nitrogen and phosphorus retention and transport, and the role of stream bank and bed sediments as	**Short term** Better water quality results from the development of practices based on the identification of in-stream processes impacting nutrients

Tifton, GA; University Park, PA; West Lafayette, IN **Cooperators** ARS-Tifton, GA, ARS-West Lafayette, IN, Des Moines Water Works, EPA, U. of ID Connell, U. of GA, U. of ID, USACOE-ERDC, USGS	Field studies to assess seasonal trends and storm effects on stream-bed sediment concentrations of pathogens and pharmaceuticals. Field studies to develop and test research techniques and automated data collection technologies that elucidate sources and removal mechanisms of water borne contaminants. Field and lab studies to assess occurrence and bioavailability of pesticides and pharmaceutically active compounds in streambed sediments. Integrate transport models for dissolved contaminants and sediment attached contaminants with water quality models considering reaction rate controlled transformations of dissolved contaminants and adsorption/desorption of contaminants attached to the sediments. Develop a multi-objective and multi-constraint optimization module to identify the best compromised decision.	sources or sinks for pesticides, pharmaceuticals, and pathogenic bacteria. 2.2.2.2 More accurate, comprehensive, and integrated contaminant transport and water quality models that account for physical, chemical, and biological processes and relate effectiveness of edge of field practices to water quality impacts at the mouth of the stream.	pesticides, pharmaceuticals, and pathogenic bacteria **Long term** Natural resources and associated ecosystem services are improved by informed management decisions and risk assessment that better relate effects of edge of field practices to water quality impacts at the mouth of the stream.

	Addition of water quality components and simulation capabilities to a process-based erosion model (WEPP)		
2.3. Ecological response to improved water quality			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 2.3 Leaders Columbus, OH: P. Smiley Oxford, MS: M. Moore **Product Locations** Columbus, OH; Oxford, MS; West Lafayette, IN **Cooperators** AR State U., IUPU-Fort Wayne, USACOE	Conduct field studies to quantify ecological responses (i.e. aquatic biota or habitat) to improve water quality through management practices, habitat improvement, or channel erosion control, and to evaluate aquatic biota relationships with water chemistry and / or physical habitat characteristics	2.3.1 New information on ecological responses to water quality improvements resulting from reduction of agricultural contaminants, enhanced, in-stream habitat structure, and stable channel geomorphology.	**Short term** Better understanding of aquatic ecosystem services in agricultural landscapes due to improved ability to predict aquatic ecosystem responses to improved water quality, in-stream habitat and channel stability. **Long term** Enhanced sound-science decision making for development of TMDLs, nutrient criteria, and restoration strategies capable of improving water quality, ecological integrity, and ecosystem services within agricultural landscapes.
2.4. Development and testing of cost-effective control measures for agriculture, urban, and turf systems			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 2.4.1 Leaders Oxford. MS: D. Wren Stillwater, OK: G. Hanson **Product Locations** Oxford, MS; Stillwater, OK	Conduct physical models on earthen embankments and steep channels that simulate complex geometries and soil material compositions to evaluate erosion processes and impact of alternative surface protection methods.	2.4.1.1 Technologies to assess the performance of, and to predict erosion from earth embankments (dams and levees): 2.4.1.2 Development of Windows Dam	**Short term** WinDAM modules that apply to multiple materials and more complex settings, including embankments with berms and convergence of the groins at the

Cooperators CEATI-DSIG, CO State U., Deltares, Netherlands, DHS, EDF, HR Wallingford, Mitch Neilsen, NRCS, Darrel Temple, U. of MS, USACE, USBR	The data from these tests will be used to validate predictive algorithms developed for inclusion in computer modules Conduct scaled physical model studies of uniform and converging width RCC spillways, basins, and downstream rock protection. The scaled model studies will be used to develop a data base that can be used to derive generalized concepts and relations for basin dimensions and Development and use of data sets from literature review and ARS physical model data sets to validate computational model. Use wave flume to assess the relationship between wave energy and embankment erosion. Acoustic and geophysical instrumentation will be used on large scale physical models and known embankments in the field with variations in internal structure and foundations. Data sets will be collected and used to validate the applicability of instrumentation for rapid assessment of internal structure of earthen embankments.	Analysis Modules (WinDAM) to predict erosion of complex embankment geometries and composite materials, and to predict allowable overtopping flows for alternative materials including articulated concrete blocks integrated with vegetation. 2.4.1.3 Development of engineering tools for the design of stilling basins for uniform and converging width Roller Compacted Concrete Spillways and for downstream protection requirements. 2.4.1.4 Integrate and develop tools for NCCHE computational models that will predict the failure of levees and dam embankments during breaching, integrate the impact of sediment transport controls, and eco-environmental impact assessment, etc. 2.4.1.5 Development of engineering guidance for improved wave protection of earthen embankments based on needed reductions of wave energy at the shoreline soil/water interface.	abutment. A tool that the engineer can use to evaluate alternative surface protection practices. Generalized engineering design tools for roller compacted concrete (RCC) have been developed for predicting flow bulking and design of training walls on uniform and converging spillways. This proposed work will result in generalized design criteria for the dimensions of the spillway stilling basin and required protection downstream. Integration of these tools will result in a NCCHE computational model that will have broader application for engineers analyzing more complex systems involving flood routing, sediment transport, levee failure, and eco-environmental impact. Improved engineering guidance for wave protection of embankments will result in methods that are more economically suitable, and in sustainable bank protection The acoustic and geophysical data will

	Remote monitoring instrumentation will be installed on large scale physical models and known embankments in the field with ongoing internal erosion and seepage processes. Data sets will be collected and used to validate the applicability of instrumentation for monitoring the temporal evolution of degradation of earthen embankments.	2.4.1.6 Acoustic and orthogonal geophysical methods for rapid assessment of the internal structure of earthen dams. The output will consist of ground-based acoustic and geophysical methods as well as archival publications. 2.4.1.7 Remote monitoring of earthen embankments. The output will be an intelligent sensor-based system consisting of a suite of *in-situ* geotechnical and geophysical sensors, data acquisition systems, remote data transfer, and decision criteria for monitoring earthen dams.	provide necessary 2D and 3D information about the internal structure of earthen embankments and their foundations. These data will be used to assist in the early detection of internal flaws that could lead to failure by internal erosion. Remote monitoring of data will be used to provide continuous, real-time information about the internal structure of earthen embankments and their foundations. This data will be used to assist in the early detection of the dynamic behavior of earthen dams that could lead to failure. **Long term** A stand alone Windows based dam analysis model as a tool for the engineer that can be used to evaluate allowable embankment overtopping, predict dam failure from overtopping and internal erosion for homogeneous and composite materials and complex geometry effects as well as alternative surface protection methods including bare earth, vegetation, rip-rap, and articulated concrete blocks.

			A generalized tool as a final product that integrates all of the research work on RCC so that the engineer can determine air entrainment, energy dissipation, convergence effects, training wall height requirements, basin length and wall height requirements, and downstream protection requirements. These methods will become part of an extensive toolbox to assess the internal structure of earthen dams as well as their foundation characteristics. This will allow for an improved assessment of the integrity of these dams. By providing continuous monitoring/assessment and advanced warning of impending failures, these remote monitoring systems will provide a better measure of security for high-hazard dams.
Product 2.4.2 Leaders University Park, PA: P. Kleinman W. Lafayette, IN: D. Smith Ft. Pierce, FL: TJ Evens Columbia, MO: R. Lerch	Development of methods to track the stability of degradative genes from bacteria introduced into the soil environment for the purpose of enhancing soil degradation of organic contaminants. Development of novel	2.4.2.1 New and improved cost-effective management practices and technologies including algal-based systems, bioremediation, and phytoremediation	**Short term** Reduced contaminant loadings to surface and shallow ground waters. Identification of the primary factors controlling biologically-based treatment technology improves water quality

Product Locations Columbia, MO; Columbus, OH; Coshocton, OH; Ft. Pierce, FL; Oxford, MS; St. Paul, MN; Temple, TX; University Park, PA; West Lafayette, IN **Cooperators** Baron and Brothers International, Constellation Energy, Cornell U., EPA Region III, FDACS, FDEP, FL Water Management Districts, Hydromentia, MT State U., NCAUR, IL, PA State U., U. of FL, U. of GA, U. of MD, U. of MD Eastern Shore, U. of DE, USDA-ARS Dale Bumpers Research Center (Booneville, AR), VA Tech. U.	biocatalysts (i.e., degradative genes attached to bacterial spores or nanoparticles) to enhance soil degradation of organic contaminants. Assess the regional potential for N removal with bioreactors Determine the effectiveness of FGD gypsum filters for reducing soluble P concentrations in surface and groundwater flow. Lab/field studies to quantify potential of soil amendments (i.e. biochar, olive mill waste, FGD gypsum) to reduce concentration of dissolved phase contaminants in soils. Collect additional field-scale data to evaluate prediction tools. Conduct studies to enhance SWAT model representation of P transport in the environment. Enhance field-scale model (TBET) to represent additional contaminants and various climatic regions. Collect data on metals transport in the environment.	approaches, for mitigating the transport of nutrients, pesticides, pathogens, metals, and emerging contaminants in agriculturally impacted waters.	management. Improved ability to predict the effectiveness of new and innovative treatment technologies on nutrient, pesticide, pathogen, metals, and emerging contaminant transport improves water quality management. **Long term** Reductions in offsite contaminant transport leading to reductions in the occurrence and areal extent of impaired zones in fresh and saline waters. Water quality is significantly improved because widespread implementation of innovative treatment technologies reduces contaminant transport. Growers are better able to meet water quality standards. Basis established for determining trading ratios to support the development of environmental markets. Development of value-added products from biologically-based treatment technologies.

	Explore the role of phosphorus stratification in soils as a cause of greater phosphorus losses to water, and developing methodologies to minimize those risks.		

* The short-term outcomes will be accomplished in the next five years.
** The long-term outcomes will not be fully accomplished in five years given current personnel and physical resources, but significant progress will be made.
*** These scientists are conducting research primarily in the ARS National Program numbered in parentheses.
**** Product users are for products shown in each subproblem area.

Problem Area 3 – Improving Conservation Effectiveness

Problem Statement

Rationale. The magnitude of annual Federal expenditures for conservation programs (at least **$**4B per year) necessitates that the cost of conservation practices implemented through those programs be evaluated 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.

Multiple conservation practices are applied to a wide variety of landscapes and agroecosystems, but the complex interactions of such practices within watersheds and at varying scales are difficult to quantify, while in some agricultural systems, new conservation approaches are needed. Advances in remote sensing and geographic systems analysis offer opportunities to target conservation to achieve better effectiveness at the watershed scale. For many conservation practices, more complete information is needed on how they impact the transport pathways taken by water and contaminants and the processes involved in contaminant mitigation. In all watersheds where water quality improvements are being sought, the effects of practices on contaminant fluxes must be quantified. Experiments directly measuring the environmental benefits of individual conservation-practices, as well as how those benefits are expressed at the watershed scale, are required both to provide the scientific basis to inform process modeling, but more importantly to validate the effectiveness of current conservation efforts at the landscape scale. Implementing these scientific advances will require collaborative partnerships through which model validation can occur in a variety of watersheds.

Research Needs. The evaluation of conservation practices in mixed land-use watersheds requires the integration of research and information from various scales. While decisions about the implementation of conservation practices are typically made at the small field or single crop scale—areas of uniform management where runoff and contaminant transport originate, watersheds integrate numerous field-scale units across variations in land use, topography, geology, soils, and climate. When attempting to quantify the effects of conservation practices at the watershed or landscape scale, these combined effects pose significant scientific and technological challenges. Limited research and technology are available to describe the complex interactions of processes that occur as scale increases, causing difficulties in determining the downstream impacts of conservation practices on water availability and quality. To translate conservation effects from the field to the watershed scale, it is critical to understand how scales and processes interact.

While agricultural impacts on hydrology and water quality can be mitigated through a variety of in-field and field-edge conservation practices, strategies that optimize both production and environmental endpoints for agriculture are needed. Current knowledge used in conservation planning is focused at the field scale, but conservation science is beginning to produce tools to deploy conservation practices to achieve landscape-scale goals—an approach necessitated by the diffuse (i.e., non-point source) nature of the material flows involved. The concept of conservation targeting (i.e., precision conservation), which attempts to optimize conservation efforts at the landscape scale, requires the integration of diverse types of information, including a better understanding of key hydrologic and biogeochemical processes, to select and place practices on the landscape for maximum environmental benefit. Research is needed to develop and deliver precision conservation tools and guidelines that are scientifically and socially defensible and that can improve watershed management and the resilience of agricultural systems.

While much is known about the *provisioning* ecosystem services that agriculture provides (i.e., food, fiber, feed, and fuel), more quantitative data are needed to assess the impact of conservation practices on *supporting* and *regulating* ecosystem services within the context of water resource management (e.g., water quality, aquatic and wetland ecosystem function, and biodiversity). Within the context of both physical structures and climatic conditions, quantitative information on ecosystem services is needed to provide a cohesive national strategy to optimize available non-market ecosystem services in agricultural landscapes. Because applications have not been developed to predict how aquatic ecosystems or physical habitat respond to changes in agricultural watersheds resulting from conservation practices, watershed models (e.g., annAGNPS, SWAT) are limited, and new data collection and modeling efforts are needed to understand these responses. Research is also needed to identify and quantify unintended consequences of changes in management, that can have significant lag times requiring longer-term assessments.

Agricultural soils, landscapes, and watersheds are most vulnerable to damage during extreme events, such as severe storms that can cause significant erosion and flooding, or prolonged droughts that reduce plant cover. Yet our knowledge of the effects of conservation practices was developed over a short and relatively recent time period. Most conservation planning and assessment tools utilize long-term averages of climate and contaminant transport, and are not designed to account for extreme events. Climate change and the dynamic nature of weather patterns raise questions about the effectiveness of current practices under climatic conditions outside those under which these practices were designed to be effective. Practices may need to be optimized to accommodate a broader range of weather and climate conditions, perhaps resulting in risk-based design tools or recommendations for worst-case scenarios.

Land-use changes, such as the expected increase in the production of bioenergy feedstocks, pose challenges and present opportunities to enhance agricultural landscapes. For example, the harvest and removal of bioenergy feedstocks from Conservation Reserve Program (CRP), buffers, or highly erodible lands may limit some of the diverse conservation benefits derived from these practices; such impacts need to be determined. Additionally, shifts from agricultural to urban land uses may diminish the resilience of associated natural systems under changing climatic conditions, and may require the development of new conservation practices and/or approaches for mixed, fragmented landscapes to maintain the functioning of hydrologic and water quality systems.

Voluntary adoption of conservation practices depends in part on the economics of those practices in combination with incentives offered through conservation programs. The ARS has the technical expertise and experimental resources to quantify the physical and biological effects of conservation practices, but partnerships will be required to incorporate key social and economic drivers and consequences. Research is needed to combine information on the biophysical effects of conservation practices with their economic and social aspects, to improve the overall effectiveness of conservation program delivery. Past successful efforts (e.g., the Upper San Pedro Partnership) could serve as models for establishing similar partnerships across ARS' network of Benchmark Watersheds.

Topics to be addressed in this problem area include:

- **3.1 Improving our understanding of the aggregate effects of conservation practices at the watershed scale**
- **3.2 Improving our ability to select and place conservation practices on the landscape for maximum effectiveness**
- **3.3 Improving conservation practices to better protect water resources**
- **3.4 Maintaining the effectiveness of conservation practices under changing climate and land use**
- **3.5 Understanding how conservation practices affect ecosystem services**
- **3.6 Developing a better understanding of the economic impacts and social drivers of conservation practice adoption in agricultural watersheds**

Problem Area 3 – Improving Conservation Effectiveness

3.1 Improving our understanding of the aggregate effects of conservation practices at the watershed scale			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 3.1 Leaders Beltsville, MD: A. Sadeghi Oxford, MS: R. Bingner El Reno, OK: J. Steiner **Product Locations** Ames, IA; Beltsville, MD; Columbia, MO; Columbus, OH; El Reno, OK; Kimberly, ID; Oxford, MS; Temple, TX; Tifton, GA; University Park, PA; West Lafayette, IN; Woodward, OK (215) **Cooperators** Federal and State NRCS, MD Dept. of Ag., U. of Georgia, U. of MD Eastern Shore, USGS,	Field studies to develop remote sensing tools to better evaluate cover crop performance. Develop models/decision support tools to assess the effectiveness of cover crops and other BMP's at the watershed scale. Enhance the landscape version of SWAT to better represent field-to-basin scale processes.	3.1.1 Knowledge, tools, and technologies to scale individual or suites of conservation practices from field to larger scales 3.1.2 Calibrated/validated models and remote sensing-based algorithms to evaluate the effectiveness of conservation practices across multiple scales 3.1.3 Completed archiving of watershed data in STEWARDS for all croplands CEAP watersheds, providing a comprehensive, accessible database to support further research, analysis, and modeling.	**Short term** Increased understanding of the effectiveness of conservation practices at multiple scales improves environmental quality and the effectiveness of conservation delivery in agricultural watersheds. Improved linkages of data to field and watershed process-based models increase the credibility and policy relevance of ARS CEAP research. The overall impact of ARS CEAP research is increased due to the increased efficiency and effectiveness of multiple location research assessments and collaborative efforts. **Long term** The sustainability of agricultural production systems is increased through more efficient implementation of conservation practices at multiple scales. Responses to emerging issues are more rapid because the utility of long-term data to address multi-decadal processes is enhanced.
3.2 Improving our ability to select and place conservation practices on the landscape for maximum effectiveness			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 3.2 Leaders Ames, IA: M. Tomer Columbia, MO: J. Sadler El Reno, OK: P. Starks	Develop mapping techniques for placing specific practices within watersheds based on	3.2.1. Knowledge and tools to aid in the selection and placement of conservation practices	**Short term** Soil and water conservation are improved by the

Product Locations Ames, IA; Columbia, MO; El Reno, OK; Ft. Collins, CO; Oxford, MS; Temple, TX; Tifton GA; University Park, PA; West Lafayette, IN **Cooperators** NRCS, Soil and Water Conservation Districts, State agencies, U. of Georgia, US-EPA, USGS	terrain and soils data. Develop methods of terrain analysis for improved mapping of soil wetness in glacial terrain. Validate the CEAP National Assessment conducted with SWAT at multiple scales. Develop field-to-watershed scale modeling tools and techniques that quantify environmental outcomes of conservation practices in major agricultural regions. Develop OMS (Object Modeling System) - based decision aids for drainage water management. Assess and compare the trade-offs of no-till adoption, and support the development of nutrient management recommendations for water quality protection, at the watershed scale.	in agricultural landscapes. 3.2.2. Model applications that adequately simulate the benefits of precision conservation tools developed and tested across multiple watersheds. 3.2.3 A spatially distributed simulation model, with hydrologic and chemical interactions across field-to-watershed scales, that predicts environmental outcomes of conservation practices, complex water quality processes, and their interaction, at the watershed/landscape scale. 3.2.4. In participatory research with conservationists, conservation targeting tools deployed in experimental watersheds to document the range of benefits provided by complementary sets of conservation practices deployed in environmentally sensitive locations.	evaluation and improvement of existing tools for the selection and placement of conservation practices. Credibility and conservation outcomes are improved by the availability of validated site assessment tools for conservation planning, and improved science-based guidance for practice placement and implementation at local, regional, and national scales. **Long term** USDA conservation programs become demonstrably more cost-effective because the development of new tools for the selection and placement of conservation practices increases the cost-benefit ratio of USDA conservation expenditures.
3.3 Improving conservation practices to better protect water resources			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 3.3 Leaders Beltsville, MD: G. McCarty University Park, PA: R. Bryant **Product Locations** Ames, IA; Beltsville, MD; Columbus, OH; Coshocton, OH; Florence, SC; Oxford, MS; Temple, TX; Tifton, GA;	Quantify nutrient management effects on water quality at field and watershed scales. Assess the impact of conservation practices on denitrification, including microbial community changes and nitrous oxide emissions. Watershed scale studies to systematically validate phosphorus site assessment tools in	3.3.1 Improved conservation practices for managing water quantity and quality within agricultural and urban landscapes to achieve multiple end-points. 3.3.2 Methods to distinguish pollutant sources from landscapes as a result of agricultural conservation practices.	**Short term** Producers and conservation planners have a broader and more versatile array of individual or combined conservation practices to address conservation concerns. Urban runoff is reduced, and urban water quality improved, due to improved restoration of urban soils following construction.

University Park, PA; West Lafayette, IN; Woodward, OK (215) **Cooperators** AR State U., IA Assoc. Municipal Utilities, MS State U., NRCS, PA State U., U. of AR, U. of GA, U. of MD Eastern Shore, USDA- SERA-17, US-EPA	support of NRCS 590 (nutrient management) standard. Integrate assessment tools for Cropland, Rangeland, and Pastureland CEAP. Watershed scale assessment of combined conservation practices. Assessments of practices that can reduce runoff from, and facilitate re-vegetation of, urban soils following construction.		**Long term** New practices enable conservation planners and landowners to be more flexible and effective in addressing water quality concerns across the full range of the nation's agricultural landscapes.
3.4 Maintaining the effectiveness of conservation practices under changing climate and land use			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 3.4 Leader West Lafayette, IN: D. Smith **Product Locations** Coshocton, OH; El Reno, OK; Temple, TX; West Lafayette, IN **Cooperators**	Use reservoir sedimentation, land use change, and climate information to anticipate future reservoir sedimentation and needs for additional conservation under changing climate. Enhance SWAT model routines for urban landscape BMPs. Apply erosion (WEPP, etc.) and water quality (WEPP-WQ, etc.) models to catchments ranging from field- to farm-size and watershed scale, to assess the impacts of current and alternative land management systems and conservation practices under current and future climates.	3.4.1. Effectiveness assessment of targeted conservation practices to address concerns relating to sediment movement and water quality in the face of possible future climate conditions and extreme climate events (e.g., drought; precipitation/runoff) 3.4.2. Assessment of conservation needs that considers multiple resources (e.g., water quantity and quality, greenhouse gasses, wildlife, etc.) to address land use change, increased biofuel crop production, and the intensification of crop production linked to population growth.	**Short term** Soil and water resources are better protected because conservation practices are resilient in the face of extreme events and projected climate change. Benefits of candidate practices demonstrated for multiple objectives (e.g., conservation; production), including practices to address changes in hydrology with urbanization at the urban-to-rural interface. **Long term** Improved capability to predict the environmental impacts of climate change and extreme events makes long-term planning more effective. As new production systems (e.g. bioenergy feedstocks) are introduced, suites of new conservation practices are available to maintain or enhance our natural

			resources.

3.5 Understanding how conservation practices affect ecosystem services

Inputs/Resources	Proposed Research	Outputs/Products	Outcomes
Product 3.5 Leaders Oxford, MS: R. Lizotte, M. Locke Tifton GA: R. Lowrance **Product Locations** Ames, IA; Brooksville, FL; Columbus, OH; Houma, LA; Oxford, MS; Tifton, GA; West Lafayette, IN **Cooperators** AR State U., IN U.-Purdue U.-Fort Wayne, U. of FL, U. of GA, U. of MS	Ecological assessments in the St Joseph River, Upper Big Walnut Creek, and Beasley Lake watersheds. As conservation practices, examine the effects of constructed wetlands and aquatic vegetation on ecosystem services. Develop analysis techniques to quantify tradeoffs for enhancing ecosystem services associated with the placement of bioenergy feedstock production systems, conservation reserve areas, and alternative management practices for enhancing ecosystem services on the landscape**.**	3.5.1. Scientific information on the influence of conservation practices and watershed characteristics on ecosystem services provided by agricultural watersheds. 3.5.2. Data and assessments of relevant ecological processes and suites of ecosystem services. 3.5.3 *Multi-Location Project:* Indicators of Ecosystem Services in Agricultural Watersheds & Landscapes	**Short term** Enhanced ecosystem services are provided by agricultural watersheds because new information is provided to support the development of improved watershed management strategies. Policies are developed that avoid adverse unintended consequences, because the effects of agro-ecosystem type, conservation practices, climatic conditions, and watershed characteristics on the ecosystem services provided by agricultural watersheds are quantified. **Long term** The ecosystem services provided by agricultural watersheds are improved by information that supports the development of new watershed management strategies. Use of market-based or other economic measures as incentives or cost-shares is enabled by the provision of a suite of ecosystem service indicators that support assigning economic or other values to ecosystem services provided by conservation practices.

3.6 Developing a better understanding of the economic impacts and social drivers of conservation practice adoption in agricultural watersheds

Inputs/Resources	Proposed Research	Outputs/Products	Outcomes
Product 3.6 Leaders Tucson, AZ: P. Heilman	Integrate physical, social, and economic factors to better assess the	3.6.1. Databases of conservation effects, calibrated watershed	**Short term** The economic efficiency and social effectiveness

Product Locations Bushland, TX; El Reno, OK; Tucson, AZ **Cooperators** ARS Corvallis, OR, ERS, KS State U., NIFA, NRCS, OH State U., TX A&M U., TX Tech U.	effectiveness of USDA conservation practices and programs. Estimate the economic impacts of alternative water conservation strategies.	simulations with and without conservation practices, and collaboratively produced studies of the costs and benefits of management practices implemented through conservation programs. 3.6.2 Estimates of the economic and social impacts of water management practices and strategies at farm, water district, and regional scales.	of conservation practices and programs is improved. Producers adopt new irrigation water management strategies because they are economically viable. **Long term** Improved effectiveness of USDA conservation programs in reducing environmental problems from agriculture. A policy framework improves long-term, sustainable management of important aquifers.

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

Problem Statement

Rationale. 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. Increasingly, this is done across heterogeneous agricultural and urban landscapes. Integrated watershed and landscape management, based on multiple objectives that include the provision of ecosystem services such as a clean and abundant water supply, agricultural (food, fiber, and fuel) production, improved wildlife habitat, greenhouse gas reduction, soil stabilization, recreational opportunities, reduced energy consumption, and reduction of urban wastes, is a complex task 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.

The interactions among ecosystems in an agricultural landscape are regulated by land use and management decisions (e.g., crops, domestic animals, fertilizer, tillage) and the organization of landscape characteristics and features interacting with weather, hydrology, and edaphic factors (e.g., soil water content, acidity, aeration, and nutrient availability). The primary challenge remains the development and application of an integrated research approach that is explicitly designed to elucidate the integrity, production capacity, and resilience of ecosystems within and surrounding agricultural landscapes, and to clearly describe the quantities and pathways of energy, matter, and water exchanges within and between ecosystems and among agricultural landscapes. Because water is one of the main connectors transporting material in agricultural landscapes, research that improves our understanding of water's flow paths through, and residence times within, these ecosystems will provide a better watershed-scale understanding of the processes controlling the provision of ecosystem services. Operating a national network of experimental watersheds, ARS is uniquely situated to address these questions. Among other things, long-term studies allow observation of changes that occur at different time-scales, and the separation of annual weather variations from directed climatic change. Thus long-term and continuous observations from these watersheds enable the development of an integrated approach to food, fiber and fuel production, watershed management, flood/drought risk evaluation, water supply management, ecosystem restoration, habitat maintenance, and the assessment of other water-related issues across broad regions of the continental United States.

Research Needs. Both fundamental research and development of tools and methodologies are required to address and resolve issues related to watershed management and the provision of ecosystem services. Tools are needed to assess and improve aquatic habitats, riparian buffers, wetlands, and streams, and to evaluate the utility of conservation practices for ensuring ecological integrity. Remotely-sensed and geospatial information are needed to support assessment of the health of agricultural landscapes, and to target the placement of crops and conservation measures to facilitate water resources management and improve environmental quality in mixed agricultural and urban landscapes. NRCS and action agencies have requested technologies and decision support systems that enhance our understanding of how dam decommissioning, rehabilitation, and construction affect fluvial and ecological systems. Investigations are needed to identify the existence and impact of regional climate variations on water availability and management, including the identification of risk of drought and the occurrence of climate extremes. Also, the utility and applicability of climate forecasts for strategic and tactical planning in agricultural production and water resource management must be explored to take advantage of recent advances in climate/atmospheric sciences. Further research and development are needed to improve comprehensive simulation models for watershed processes, plant productivity, and environmental response assessment under variable climate, changing land use, increasing urban activity, and ecosystem restoration efforts. These scientific research activities, tool developments, simulation model investigations, conservation practice evaluations, and environmental enhancement efforts must be supported by new remote sensing tools and enhanced instrumentation for watershed-scale evapotranspiration and coupled carbon fluxes, soil moisture, snow accumulation and melt, water budgets, and water stress estimation, mapping, and interpretation. These needs will be built on existing ARS expertise and offer an integrated research and development approach that enhances the beneficial utilization of land and water resources in agricultural landscapes, and meets today's competitive and multi-objective management of land and water resources.

In this problem area of the NP 211 Action Plan, ARS and USDA Experimental Watersheds, Ranges, and Forests provide a foundation for the multi-site research, analysis, and synthesis outlined in the table below. These multi-site projects will systematically test common hypotheses at locations across the continental United States, using long-term, high-resolution observations in time and space. This approach will enable broad scale interpretations and conclusions across a range of major agricultural production regions, biomes, and hydro-climatic zones.

ARS customers have requested decision support tools that are user friendly, have broader applicability, are interoperable, and can provide multiple objective outcomes (water quantity, water quality, optimized crop yield, and provision of quantifiable ecosystem services that can be traded as commodities). The development and ongoing support of such tools requires applied research on how to monitor ecosystems at appropriate spatial and temporal scales, the design and deployment of data collection tools and sensors to track variations in process responses, and the translation of temporal and geospatial data trends into reliable indicators of agro-ecosystem resiliency and metrics of ecosystem service provisioning. Effective use of these tools requires the collection of long-term data, model improvement, calibration and application, and the development of national datasets that facilitate the use of model and user applications (e.g., smart phone or iPad) to synthesize agro-ecosystem service capacities into scalable management options.

Topics to be addressed in this problem area include:

- **4.1 Developing tools to improve hydrologic assessment and watershed management**
- **4.2 Improving watershed management and ecosystem services through long-term observation and characterization of agricultural watersheds and landscapes**
- **4.3 Maintaining water availability in a changing global environment**
- **4.4 Developing tools to improve the quantification of hydrologic processes and water budget parameters in varying landscapes and under varying conditions.**
- **4.5 Understanding the water implications of biofuel production**
- **4.6 Downscaling climate change impacts to improve water availability and watershed management**

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

4.1 Developing tools to improve hydrologic assessment and watershed management			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.1 Leaders Beltsville, MD: W. Crow Ft. Collins, CO: J. Ascough Oxford, MS: R. Bingner	Integrate assessment tools for Cropland, Rangeland, and Pastureland CEAP. Develop a web-based interface for spatial	4.1.1. Integrated tools for better multi-scale (field-to-watershed) decision support for management practices in regions across the nation.	**Short term** Management of agricultural watersheds/landscapes is improved by using models and remotely sensed data to develop

Temple, TX: J. Arnold **Product Locations** Beltsville, MD; Columbia, MO; El Reno, OK; Ft. Collins, CO; Las Cruces, NM (215); Mandan, ND (212; 215; 216); Morris, MN (212; 216); Oxford, MS; Temple, TX; Tifton, GA; Tucson, AZ; University Park, PA; Weslaco, TX; West Lafayette, IN **Cooperators** MI State U., Turfscout LLC, U. of AZ, U. of GA, U. of NH, U. of SC	watershed scenario analysis. Multi-scale studies to calibrate, validate, and evaluate complex decision support tools integrated with economics and crop production. Multi-scale studies quantifying the incremental value added by assimilating multiple remote sensing surface moisture indicators into hydrologic models. Multi-scale studies of remote sensing techniques for mapping drought and water use.	4.1.2. *Multi-Location Project:* Utility of Remote Sensing for ET and Drought Monitoring and for Assimilation into ARS Hydrologic Models	a better understanding of the linkages between plant growth, soil and environmental processes, landscape position, and hydrologic connectivity over large areas. Greater confidence watershed management strategies developed utilizing remotely-sensed data and agro-ecohydrology models to quantify important hydrologic, biogeochemical, and climatic processes and effects. **Long term** Management strategies increase the sustainability of agricultural production and natural resource delivery, because decision support tools more accurately represent exchanges of energy, water, and materials between landscape components in fields, farms, watersheds, and eco-regions.
4.2 Improving watershed management and ecosystem services through long-term observation and characterization of agricultural watersheds and landscapes			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.2 Leaders Ames, IA: T. Moorman Columbia, MO: J. Sadler Corvallis, OR: G. Whittaker Las Cruces, NM: J. Herrick Tifton, GA: T.	Improve the observational capability and data accessibility of ARS Experimental Watersheds and Ranges, including updating and maintaining the	4.2.1. Improved long-term watershed characterization and data access services. 4.2.2. Synthesize information and observations into appropriate (i.e. policy-	**Short term** Management of agricultural watersheds/landscapes and the delivery of ecosystem services are improved by the availability of high-quality, long-term data

Strickland **Product Locations** Ames, IA; Beltsville, MD; Boise, ID; Columbia, MO; Columbus, OH; Corvallis, OR Coshocton, OH; El Reno, OK; Fort Collins, CO; Las Cruces, NM (215); Morris, MN (212, 216); Oxford, MS; Temple, TX; Tifton, GA; Tucson, AZ; University Park, PA; West Lafayette, IN; **Cooperators** Consortium of Univ. for the Advancement of Hydrological Sciences, Inc. (CUAHSI), National Agricultural Library	STEWARDS database. Develop biome-specific descriptive statistics on the relationship between precipitation and annual net primary productivity on working lands. Develop a reference baseline for measuring changes in production capacity in response to environmental conditions and management decisions. Develop robust indicators, statistics and biome-specific metrics of the: 1) spatial and temporal connectivity of landscape elements; 2) quantity and quality of ecosystem services provided by agricultural landscapes;	friendly) formats. 4.2.3 *Multi-Location Projects:* Indicators of Ecosystem Services in Agricultural Watersheds & Landscapes. 4.2.4. Remotely-derived estimates of Net Primary Production using remotely sensed data across Precipitation Regimes.	on the spatial and temporal variation of major environmental driving variables related to provisioning, regulating, and supporting ecosystem services (e.g., water quantity & quality; agricultural, forest, and range productivity; wildlife habitat; biodiversity). Broad improvement in decision-making capacity because ready access to accurate data enables the development of climate-informed decision support for a wide range of applications. **Long term** Calibration and interpretation of assessments from broad-based inventories, surveys, and remote sensing programs on working lands is improved through enhanced data availability. Because of the availability of necessary data and observations, calibration and validation of watershed, production, and ecosystem services models occur more rapidly, enhancing agricultural watershed/landscape management, and the

			provision of ecosystems services. Management of agricultural watersheds/landscapes and provision of ecosystem services is more effective because existing databases of ecosystem provisioning services (e.g., regional distributions of carbon, water, and nutrients with descriptive spatial statistics) and supporting models are more robust.
4.3 Maintaining water availability in a changing global environment			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.3 Leaders Boise, ID: M. Seyfried Fort Collins, CO: T. Green Tucson, AZ: D. Goodrich **Product Locations** Beltsville, MD; Boise, ID; Bushland, TX; Columbia, MO; Coshocton, OH; El Reno, OK; Ft. Collins, CO; Las Cruces, NM (215); Mandan, ND (212, 215, 216); Maricopa, AZ; Oxford, MS; Temple, TX; Tifton, GA; Tucson, AZ; University Park, PA; West Lafayette, IN; **Cooperators** Biosphere2, BLM, Duke U., NRCS, PA State U., U. of AZ, U.	Determination of soil/snow energy balance in variable terrain. Measure water and CO2 fluxes in complex terrain. Synthetic and real data testing of new data assimilation techniques for incorporating remote sensing observations into land surface models. Identify universal hydro-climatic descriptors of watersheds and determine the significance of historical trends in temperature, precipitation, and runoff across North America.	4.3.1. A verified, multi-scale snowmelt model to assess water supply along an elevation gradient. 4.3.2. Large-area, process-oriented, watershed models that incorporate remote sensing data. 4.3.3. Improved models to simulate the effects of multiple drivers (e.g., climate; land use change) and edaphic parameters (e.g., how topography or crop residue affect soil energy balance) on water supply. <u>4.3.4. *Multi-Location Projects:*</u> Hydro-Climatic Trends characterized across North America.—A comparative analysis	**Short term** Improved future water management due to: 1) improved understanding of the effects of topography and land cover on CO_2 and water balance in mountainous terrain; 2) improved understanding of the regional feedbacks between atmospheric climate, vegetative cover, and soil climatology; 3) improved simulation of watershed processes, agricultural management, plant growth, tile drainage, weather generation, evapotranspiration, carbon fluxes, surface-groundwater interactions, and data assimilation tools for

of CA, U. of ID, U. of Miami, U. of Reading, U. of Saskatchewan, Marmot Creek, AL, U. of TX, USDA-Forest Service, USGS	Develop improved plant growth models and model parameters for NRCS rangeland and pastureland CEAP (ALMANAC). Continue development and validation of ARS watershed and management simulation models (e.g. SWAT, AnnAGNPS, KINEROS, AgES, AGWA, REMM, etc.) to treat a broader spectrum of conditions, management scenarios, ecosystem services, economics, and crop production.	of historical soil water trends in US agricultural lands. Continental-scale synthesis of high-resolution observations from ARS and USDA experimental watersheds, ranges, and forests, to quantify the impacts of climate variability and change on agro-ecosystems. Comparison of eddy covariance flux measurements of water vapor and CO_2 in different environments.	water budget and water quality assessment, and flood and drought risk where impacts on production and the environment are coupled under a variable and changing climate; 4) improved understanding of the regional interactions and feedbacks between atmospheric climate, vegetative cover, and soil climatology. **Long term** Improved and sustainable agricultural production due to improved prediction of watershed response, water supply, and crop production over hydro-climatic regions of the US.
4.4 Developing tools to improve the quantification of hydrologic processes and water budget parameters in varying landscapes and under varying conditions.			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.4 Leaders Beltsville, MD: W. Kustas, W. Crow, M. Cosh, M. Anderson Tifton, GA: D. Bosch Weslaco, TX: C. Yang **Product Locations** Beltsville, MD; Boise, ID; Tifton, GA; Tucson, AZ; Weslaco, TX. **Cooperators** Boise State U., NASA, NOAA, U. of AZ, U.	Intercomparison of remote sensing evapotranspiration models at multiple scales. Field studies of snow energy balance, including evaluating remote sensing models. Validation of remotely-sensed surface soil moisture using ground-based surface soil moisture networks.	4.4.1. New measurement tools (including in situ and remote sensing) for terrain, evapotranspiration, and coupled carbon fluxes, soil moisture, snow and snowmelt, vegetation characterization, and data interpretation methods for agricultural and rangeland environments.	**Short term** Water availability management is improved by greater certainty and more certain linkages between water, energy, and bio-geochemical cycles, and the improved utility of remotely-sensed products for data synthesis, spatial scaling, and regional assessment. **Long term**

of NH, U. of SC, TX A&M U.	Large-scale field experiments for testing improved soil moisture remote sensing retrieval algorithms for new satellite-based sensors. Measurement error for LIDAR acquired and quantified.	4.4.2. Improved observational technology and estimation of components of the basin water budget. 4.4.3. Methodological advances in remote sensing algorithm development.	Integration of remotely-sensed data products into operational decision support systems improves crop production and water resource monitoring and assessment.
4.5 Understanding the water implications of biofuel production			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.5 Leaders Tifton, GA: R. Lowrance **Product Locations** Dawson, GA; Houma, LA; Temple, TX; Tifton, GA **Cooperators** Ft. Valley State U., Lewis Taylor Farms, GA, U. of FL; U. of GA	For sugarcane, determine limiting input requirements for sustainable production of sugar and/or bioenergy. Assess risks of sugarcane production on ecosystem services, including soil health and water availability. Identify landscape positions where biofuel feedstock production can enhance ecosystem services. Develop BMPs for a growers guide for sustainable production of sugarcane for sugar and/or bioenergy.	4.5.1. Enhanced characterization of the water implications of using marginal lands for bioenergy feedstock production.	**Short term** Improved regional knowledge of the limiting input requirements for biofuels feedstocks increases the sustainability of biofuels production. Conflicts between food and fuel production and ecosystem services are reduced through the development of tools and methods to identify suitable locations where biofuel feedstocks can be produced sustainably. Tools and methods to quantify the costs and benefits of biofuel feedstock production and the associated risks to ecosystem services improve the economic and environmental sustainability of biofuel feedstock production. Sustainability of biofuel production systems is improved by the development and/or

			improvement of tools and methods to develop an economic-environmental suitability index for siting biofuels conversion facilities. **Long term** Sustainable biofuel production systems are developed for a variety of regions in the US.
4.6 Downscaling climate change impacts to improve water availability and watershed management			
Inputs/Resources	**Proposed Research**	**Outputs/Products**	**Outcomes**
Product 4.6 Leaders El Reno, OK: J. Garbrecht, J. Schneider, J. Zhang, **Product Locations** Columbia, MO; Coshocton, OH; Dawson, GA; El Reno, OK: Houma, LA; Oxford, MS; Temple, TX: Tifton, GA; Tucson, AZ; University Park, PA; **Cooperators** U. of AZ	Assess existing climatologies, developing and applying QA/QC as needed, testing and applying calibrations and/or interpolation for missing data. Examine the utility of recent climate forecasts, investigate the value of sub-monthly climatologies in modeling of seedling establishment, and develop a tool for monitoring seedling environment. Develop methodology to incorporate climate change capabilities into weather generation models. Develop and validate mathematic downscaling relationships with historical climate Develop the linkages between climate	4.6.1. Improved spatio-temporal downscaling techniques for better simulating climate change impacts on soil erosion and crop production using new weather generators. 4.6.2. Place-specific climatologies for downscaling climate forecasts, initializing weather generators, and elucidating historical interactions between climate, crop management, and productivity. 4.6.3. Monthly and sub-monthly climatologies and forecasts are incorporated in decision support for forage seedling establishment. <u>4.6.4 *Multi-Location Projects:*</u> Estimate the impacts of projected climate	**Short term** Ready access to relevant and accurate data enables the development of climate-informed decision support systems for a wide range of applications. Improved climate impact simulation and climate change adaptation improve water availability and watershed management in agricultural landscapes. Resilience of agriculture to impending climate change is improved because the components of the hydrologic system that are most sensitive to projected climate change are identified, and related conservation needs and changes in agricultural land productivity are

	change, conservation needs, and agronomic adaptation requirements in agricultural watersheds For 2050, determine anticipated climatic and hydrologic changes, identify the components of the hydrologic system that are most sensitive to projected precipitation and air temperature changes, and infer implications for conservation needs and agricultural productivity across diverse physiographic regions of the US, using downscaled GCM data. Using SWAT, determine the impact of projected climate change on regional water availability and watershed sediment yield and their implications for agricultural productivity Develop agricultural water conservation strategies to adapt to climate change Analyze long term hydro-climatic data in a global change context.	change on regional water availability and quality (including watershed sediment yield), across diverse physiographic regions of the United States, and their associated implications for conservation needs and agricultural productivity.	determined. **Long term** Adaptation of agricultural production systems to climate change is enhanced due to improved assessment of the potential impacts of spatially variable land use and agricultural management on water quantity and agricultural productivity under historical and projected climates. Sustainability of agricultural production is maintained by improved adaptation of land resource utilization, conservation practice implementation, and agricultural production to an intensified climate. Useful climate-informed decision support is the norm for agricultural and natural resource management.

* The short-term outcomes will be accomplished in the next five years.
** The long-term outcomes will not be fully accomplished in five years given current personnel and physical resources, but significant progress will be made.

*** These scientists are conducting research primarily in the ARS National Program numbered in parentheses.
**** Product users are for products shown in each subproblem area.

A Cross-Cutting Infrastructural Entity to Support Long-Term Multi-Location Research

The Agricultural Research Service (ARS) currently maintains a network of approximately 28 Benchmark Watersheds, Experimental Ranges, and associated/related research facilities that collect long-term physical, chemical, and biological data on agricultural sustainability, climate change, ecosystem services, and natural resource conservation at the watershed or landscape scale. Data records extend from 5 to 98 years, varying with the date of establishment. The oldest of these sites—The Jornada Experimental Range in NM—was established in 1912. Research at most of these facilities is supported through the ARS' Water Availability and Watershed Management National Program (NP211).

ARS' long-term watershed/landscape scale research sites contribute to various components of the Conservation Effects Assessment Project (CEAP), particularly those for Croplands, Grazing and Pasture Lands, and Wetlands. Two of ARS' Experimental Range research sites are also part of the National Science Foundation's (NSF) Long-Term Ecological Research (LTER) Network; three have been selected to become part of NSF's proposed National Ecological Observatory Network (NEON). ARS long-term watershed/landscape scale research sites can be found in nearly all of the major farm production regions in the US. In addition to supporting high-quality, location-based research, including collaborations with the academic research community and other Federal agencies, these sites also provide the opportunity to make important comparisons across sites. While several components of this Action Plan take advantage of this opportunity, until now, these sites have functioned effectively as a loosely organized confederation rather than a truly unified, fully integrated network.

Through this Action Plan and several other mechanisms, ARS is currently seeking input from the academic and Federal research communities, and its customers and stakeholders, regarding the organization of a select number of these existing watershed and rangeland research sites into a network for long-term, geographically scalable, coordinated research in support of enhancing the sustainability of agro-ecological goods and services, including the production of agricultural commodities—a Long-Term Agro-ecosystem Research (LTAR) Network.

During the last 10 years, such a concept has been proposed in a number of highly visible publications. For example, the 2003 NRC report entitled, "Frontiers In Agricultural Research", urged the U.S. Department of Agriculture (USDA), and specifically the Research, Education, and Economics mission area (REE), to move from a narrowly focused set of research priorities to a more strategic and long-term approach to food and agricultural research. In a 2008 paper in BioScience, Robertson et al. stated that the creation of an explicitly long-term research program for agriculture—a comprehensive, systems-level research approach that was both long-term and geographically scalable (largely lacking from the US agricultural research portfolio) was long overdue. Robertson et al. specifically called for the creation of a Long-Term Agricultural Research (LTAR) program at the Federal level. Two years later, Karl Glasener echoed these sentiments in a 2010 editorial for CSA News entitled, “It’s Time for a Long-Term Agro-ecosystem Research (LTAR) Network”, suggesting that the successful LTER model be expanded to the Nation’s agricultural lands (agro-ecosystems). Most recently, the NRC, in a 2010 report entitled, “Toward Sustainable Agricultural Systems In the 21st Century”, stated that, “The U.S. Department of Agriculture should . . . develop a long-term research and extension initiative that aims to understand the aggregate effects of farming at a landscape or watershed scale.” In response to this clearly identified need, ARS is currently seeking guidance from its research partners, customers, and stakeholders, on the creation of a Long-Term Agro-ecosystem Research (LTAR) Network for agriculture.

Our **Vision** for this network would be:

Transdisciplinary science
conducted over decades
on the land in different regions,
geographically scalable,
enhancing the sustainability of agroecosystem goods and services.

The **Goal** of the LTAR Network would be:

To sustain a land-based infrastructure for research, environmental management testing, and education that enables understanding and forecasting of the Nation’s capacity to provide agricultural commodities and other ecosystem goods and services under ever-changing environmental and resource-use conditions.

Our **Approach** would be to:

- Identify a select group of sites to define the initial network, using **criteria** developed by the ARS Office of National Programs, senior area managers, and leading field scientists.
- Add additional sites (operated by either ARS or other organizations) to this network over time, based on mutual interest and their ability to meet established criteria.
- Offer this infrastructure for research and funding partnerships with other Federal agencies, universities, and the private sector.
- Seek funding, from sources such as the National Institute of Food and Agriculture (NIFA) and NSF, through appropriate partnerships, to develop technologies and processes for standardized data collection, storage, access, and the development of LTAR Network-wide synthesis products to complement other long-term, multidisciplinary, large-scale Federal research investments like the LTER Network, NEON, and etc.

Our **Fundamental Operating Principles** would be to:

- Develop research questions that are shared and coordinated across sites.
- Provide the capacity to address these large-scale questions across sites through shared research protocols.
- Collect compatible data sets across sites, and provide the capacity and infrastructure for cross-site data analysis.
- In general, facilitate and foster shared engagement in thinking and acting like a network.

As Proposed, the LTAR Network Would Be:

- A cross-cutting infrastructural entity that supports research components of ARS National Program Action Plans and the strategic/implementation plans of other organizations, and that can be described in those plans as an infrastructural resource for supporting research.
- A platform to support multi-organization research and funding efforts.
- A platform for developing and testing regional- and national-scale hypotheses that cannot be undertaken by individual locations alone.
- An organizing principle for land-based research.
- A basis for developing long-range, multi-agency/institutional funding plans.

As Proposed, the LTAR Network Would NOT be:

- A research project *per se*.
- A network for observation alone.
- A justification for redirecting or terminating currently productive research.
- A reason for abandoning location-based research.
- A project for which a project plan would be developed.
- An ARS National Program.
- A Research Component or Objective of an ARS National Program Action Plan.
- A reprogramming or redistribution of current funding appropriated to ARS locations.

Establishing an LTAR Network Would:

- Provide an organizational and activity framework to attract sustained investments for high-impact payoff.
- Make a unique ARS resource more widely available for partnerships.
- Represent an ARS response to a repeated and widely communicated challenge to the agricultural research community to address a national need.

- Potentially attract research partners for large funding opportunities.
- Help maintain the continuity of current place-based watershed/landscape scale research, while providing the ability for scaling up to regional and national scales.
- Help maintain the continuity and further organization of successful ARS programs and initiatives (e.g., CEAP; GRACEnet).
- Enable hypothesis-testing about the sustainability of agricultural systems on a large scale and in comparison with non-agricultural systems, through networks like LTER, NEON, and etc.
- Provide a basis for future USDA budget initiatives.
- Provide infrastructural support for research associated with multiple ARS National Programs, as well as the research programs of other organizations.
- Clearly identify the criteria for developing a location’s (both ARS and others) capacity to become an LTAR site.
- Foster the involvement of non-LTAR scientists.