National Program 202: Soil Resource Management
Action Plan

Part 1. Introduction

Vision
Sustaining soil and society

Mission
The mission of the Soil Resource Management National Program is to develop cost-effective soil management practices, technologies, and decision tools that enable producers, advisors, other land managers, and decision makers to enhance food, feed and fiber production while protecting soil, water, and air resources.

Background
The thin layer of soil at the surface of the earth functions as the central resource to sustain life. Soil management is one of the critical factors that control plant production, which in turn supports animal production. Soils also remove impurities to protect water and air quality. A balance needs to be reached between the short-term use of the soil and the long-term sustainability of this critical resource. Protecting, preserving, and enhancing the soil resource are key elements of this National Program.

Although people in agriculture have long recognized the importance of soils, the general public does not view soils as an important resource. Recently, *Science* magazine (June 11, 2004) identified soil as the "Final Frontier," thus drawing attention to the importance of this resource and to our incomplete knowledge of soil properties, processes, and functions. Considerable research will be needed to further understand soil physical, chemical, and biological properties and processes. This information will allow management practices and systems to be developed and evaluated for their soil, water and air quality benefits. Decision tools need to be developed to predict where management strategies should be used and the environmental benefits that will occur from application of improved practices and systems.

Goal
The goal of the Soil Resource Management National Program is to enable sustainable food, feed, and fiber production while protecting the environment. This National Program is part of Goal 5, Protect and Enhance the Nation's Natural Resource Base and Environment, of the ARS Strategic Plan (http://www.ars.usda.gov/aboutus/docs.htm?docid=1766) and the USDA - Research, Education and Economics (REE) strategic plan (http://www.csrees.usda.gov/ree/strategic_plan.htm). It also contributes to Goal 1 (Enhance Economic Opportunities for Agricultural Producers) and Goal 3 (Enhance Protection and Safety of the Nation's Agriculture and Food Supply) of these strategic plans.

Approach
Research will be conducted to understand soil physical, chemical, and biological properties and processes to allow development of soil management practices to overcome limitations to productivity while maintaining or enhancing environmental quality. Development of tools to assess the sustainability of soil management practices will be an important part of this effort. This National Program will address nine research Problem Areas based on input received at a

planning workshop (described below) and other interactions designed to identify critical problems and needs of our customers, stakeholders, and partners. The Problem Areas are listed in a general order that reflects (1) soil properties, processes and functions; (2) soil management for production; and (3) soil management for environmental protection.

- Soil Biology and Rhizosphere Ecology
- Soil Structure and Hydraulic Properties
- Soil Carbon
- Nutrient Management
- Conservation Practices and Systems
- Impact on Soil of Residue Removal for Biofuel Production
- Pesticide Fate
- Soil Erosion
- Remediation of Degraded Soils

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 research, outreach, and technology transfer. Product users such as University Extension Programs and the Natural Resources Conservation Service (NRCS) will work with us to ensure the information is in the most useable format for their organization and the expected outcomes are quickly achieved.

Planning Process and Plan Development

The second Soil Resource Management National Program workshop was held February 2005 in Dallas, Texas. Approximately 150 participants including producers, commodity group representatives, public interest group representatives, scientists from universities, and scientists and administrators from ARS and other Federal and State agencies attended this workshop. To ensure relevance of research in this National Program, input from the workshop and other activities such as USDA and interagency programs, committees, meetings attended by our scientists and national program leaders, and assessment of this national program’s impact over the previous 5 years were used to formulate the nine problem areas.

To develop each problem area, ARS scientists used the program logic model to identify outcomes, outputs, or products to be produced to achieve the outcomes, and the resources or inputs available to achieve these goals. ARS scientists at each of the laboratories participating in this and other relevant national programs (e.g., Water Resource Management, Air Quality, Global Climate Change, Manure and Byproduct Utilization, and Integrated Agricultural Systems) will use this action plan to develop project plans that describe the specific research they will conduct. The project plans provide detailed information on objectives, anticipated products or information to be generated, the approach to be used, roles and responsibilities of ARS scientists and their cooperators, and timelines and milestones to measure progress. All project plans are reviewed for scientific quality by an independent panel of experts. ARS scientists use input from the review panel to revise and improve their planned research.

Part 2. Research Problem Areas

Problem Area 1: Understanding and Managing Soil Biology and Rhizosphere Ecology

Problem Statement

Rationale: Belowground interactions among soil macro- and micro-organisms, plant roots, and root exudates influence many soil biological, chemical, and physical processes and thus play a vital role in ecosystem function, soil sustainability, and crop productivity. These properties, processes, and interactions all respond to and impact agricultural production systems. For example, in the soil and rhizosphere, beneficial soil organisms form symbiotic relationships that improve plant health and vigor. However, in many situations narrowly-focused management practices have destroyed or depleted beneficial organisms such as arbuscular mycorrhizal (AM) fungi. To develop sustainable agricultural systems, vigorous populations of beneficial soil organisms need to be promoted or reestablished.

Soil functions – nutrient cycling, pathogen suppression, stabilization of soil aggregates, and degradation of xenobiotics – are inextricably linked to the aboveground ecosystem. Root exudation, deposition of plant litter, and application of animal waste provide energy sources for microbial activity. Soil biological processes influence the rate and efficiency of many processes including nutrient supply for plant production, and interactions among climate, soil, water, and other components of the abiotic environment. Trophic interactions and predator-prey relationships within and between the soil invertebrate and microbial communities further influence nutrient mineralization rates by modifying and/or catalyzing the release of nutrients by microorganisms. Management practices imposed in agroecosystems affect soil microbial processes and rhizosphere-microorganism interactions. Inadequate understanding of soil biology and rhizosphere ecology limits development of improved management practices and tools.

Need for Research: An improved understanding of soil biology and rhizosphere ecology will facilitate development of agricultural production practices that promote resource efficiency, nutrient cycling, and ecosystem services. Basic and applied research is needed to understand functional relationships among (1) soil ecosystems (2) biological, chemical, and physical processes (e.g., plant productivity, nutrient and organic matter cycling, water-holding capacity, and aggregation), and (3) management practices.

Focus Area 1: Improved understanding of soil biology and rhizosphere ecology. Managing soil ecosystems to improve resource efficiency, minimize economic and disease risks, and promote ecosystem services and sustainability requires predictive knowledge of the relationships between biotic and abiotic soil factors, belowground food webs, soil stability, plant resource availability, and short- and long-term plant community dynamics. However, soil ecology is a relatively new field of inquiry, and many of the ecological theories and models developed for aboveground communities either do not apply or have not been tested for belowground systems. Emerging methods of molecular biology have completely transformed the field of soil biology. Development, adaptation, and testing of these new methods are critical for evaluating soil ecosystems in a consistent manner. Minimizing economic and environmental risks from soil-borne plant and human pathogens requires increased understanding of how these pathogens reside and proliferate in the soil and the development of new technologies for assessment and control. Addressing the safety concerns associated with new management practices, such as the use of genetically modified organisms and their associated pest control strategies in cropping systems, requires evaluations of management impacts on soil and rhizosphere microflora.

Focus Area 1: Improved Understanding of Soil Biology and Rhizosphere Ecology

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Leader: **1a. Fort Collins, CO**: Manter **Product Participants:** Beaver, WV Beltsville, MD Pendleton, OR Pullman, WA Stoneville, MS **Product Leaders:** **1b. Beaver, WV:** O'Neill **Beltsville, MD**: Buyer **Product Participants:** Ames, IA Beaver, WV Brookings, SD Columbia, MO Ft. Collins, CO Lubbock, TX Mandan, ND Morris, MN Pendleton, OR Pullman, WA Stoneville, MS Temple, TX Urbana, IL Watkinsville, GA **Cooperators** **Within ARS:** Beaver, WV Beltsville, MD Las Cruces, NM Lubbock, TX Pendleton, OR Sidney, MT Weslaco, TX West Lafayette, IN **Outside ARS:** University of Vermont University of Maryland South Dakota State University University of Montana	1a. New methods and equipment (including molecular techniques) to assess soil biological and ecological communities. 1b. Synthesis papers and fact sheets that assess the relationships among above-ground ecosystems (including management factors), soil ecosystems (including abiotic soil properties), the rhizosphere, soil biological communities; and the impact of these relationships on ecological processes relevant to management.	**Short-term:** (a) Increased understanding of the functional relationships between soil physical, chemical, and biological characteristics and processes; (b) Development of specific agricultural management practices and above-ground conditions that improve soil ecological structure and function; (c) Identification of disease and economic risks associated with management decisions and potential control mechanisms; and (d) Modification to the rhizosphere and soil biota to improve plant productivity and ecosystem function. **Long-term:** Improved agricultural production systems that promote resource efficiency, nutrient cycling, and ecosystem services by minimizing disease and economic risks through management of soil ecological and rhizosphere processes.

Focus Area 2: Utilizing Arbuscular Mycorrhizal (AM) fungi and other biological processes to enhance productivity, profitability, and sustainability. AM fungi form a symbiotic relationship with most plants that is vital to plant productivity. In addition, AM fungi have well documented effects on mineral nutrition, disease resistance, and water stress resistance of plants, and contribute to maintenance of soil structure, nitrogen cycling, and carbon sequestration. However, excessive cultivation and poor management decisions such as applying excessive amounts of pesticide and synthetic fertilizer have decreased the activity and efficacy of native communities of AM fungi. To reestablish low-input sustainable agricultural systems, these beneficial organisms need to be reintroduced to soil.

Basic and applied research will increase our knowledge of beneficial soil organisms, such as mycorrhizal fungi, and their role in above- and belowground ecology. Specifically, one goal is to efficiently produce large quantities of AM fungi for field inoculation to ease the transition from conventional to low-input sustainable agriculture. This research will include the continued development and expansion of methods for "on farm" production of AM fungi. Developing detailed models of carbon and nitrogen movement in the symbiosis including pathway identification, flux analysis, and gene expression will contribute significantly to our understanding of how to grow these fungi for inoculum production. In addition, methods and new technology to rapidly identify and quantify mycorrhizal infection and hyphal production are needed. New technologies and methodologies also will be used to identify and characterize biomolecules, such as glomalin, that are related to soil organic matter and soil structure and respond favorably or unfavorably depending on management.

Focus Area 2: Utilizing Beneficial Soil Biota to Enhance Productivity, Profitability and Sustainability

Inputs/Resources Locations	**Outputs/Products**	**Outcomes**
2. **Product Co-Leaders:** **Mandan, ND:** Nichols **Wyndmoor, PA:** Douds **Product Participants:** Akron, CO Wyndmoor, PA **Cooperators:** **Within ARS:** Beaver, WV Beltsville, MD Lubbock, TX **Outside ARS:** Michigan State University New Mexico State University The Rodale Institute University of Alabama University of Montana Volcani Institute, Israel South Dakota State University	2. Synthesis papers and fact sheets describing new tools, protocols, and approaches for optimizing production (including "on-farm" techniques) and quantification of arbuscular mycorrhizal fungi and for identifying, quantifying, and characterizing biomolecules, such as glomalin, produced by AM fungi.	**Short-term:** On-farm production of arbuscular mycorrhizal inocula. **Long-term:** Utilization of beneficial soil biota, such as natural mycorrhizal symbioses, for nutrient management, pest resistance and improved soil aggregation.

Problem Area 2: Soil Management to Improve Soil Structure and Hydraulic Properties

Problem Statement

Rationale: Water is the most limiting factor for crop growth and yield in most agricultural soils, accounting for approximately 80% of crop yield variability. In semi-arid regions, declining supplies of fresh water and increased competition for irrigation water from urban areas will likely reduce overall production and increase year-to-year variability in yield. Low infiltration on structurally impaired soils reduces precipitation use-efficiency by crops and increases risks of excessive runoff, erosion, and off-site pollution of water resources. Soil properties and processes affecting infiltration include surface sealing, soil surface and plow-layer structure, compaction, surface and incorporated crop residues, soil and water chemistry and salinity, and various aspects of soil biology. Natural and synthetic soil conditioners can greatly affect water infiltration and retention. Soil water availability depends not only on how much water the soil can retain, but also rainfall distribution throughout the season, lateral redistribution of water in the field, and stresses (such as compaction or aeration) that reduce crop water use. To better understand and thus more efficiently manage soil water processes, we must (1) develop adequate techniques for measuring soil water content and potential; (2) develop the ability to measure and model infiltration, evaporation, and soil water redistribution over the landscape; and (3) improve measurement of changes in soil properties that influence these processes.

Research Needs: Economically feasible soil and crop management strategies that permit more efficient storage and water use in dryland and irrigated systems are needed to increase yields where water is limiting, to improve profitability and yield stability, and to reduce dependence on scarce water resources. Innovative and cost-effective soil management strategies, products, in addition to technologies that directly or indirectly improve or modify soil structure and infiltration, are required to more efficiently use precipitation and to reduce offsite impacts in urban, suburban, and rural areas. New technologies, assessment tools, and models are required to evaluate and predict soil water availability at the landscape scale and with time. Lastly, new assessment tools and models are required to evaluate and predict changes in soil aggregation and structural stability, soil sealing and crusting, soil compaction, and infiltration as affected by management.

Problem Area 2: Soil Management to Improve Soil Structure and Hydraulic Properties

Inputs/Resources Locations	**Outputs/Products**	**Outcomes**
1. Product Leader: **Bushland, TX:** Schwartz **Product Participants:** Akron, CO Ames, IA Auburn, AL Brookings, SD Bushland, TX Kimberly, ID Lubbock/Big Spring, TX Temple, TX Watkinsville, GA	1. Improved management practices, guidelines and decision aids to optimize soil physical and hydraulic properties to improve infiltration, water retention, aeration and root proliferation for agriculture and urban land uses.	**Short term:** Improved soil structure, crop growth and yield, and reduction of surface runoff, erosion, and surface and subsurface water contamination. **Long term:** Enhanced soil productivity and sustainability, and conservation of water resources. Optimize soil water availability and use through environmentally safe soil management.
2. Product Leader: **Ames, IA:** Logsdon	2. A wider range of tools and more sensitive instrumentation to	

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Participants: Akron, CO: Auburn, AL Beltsville, MD Bushland, TX Columbia, MO Oxford, TX **Cooperators:** Iowa State University Texas Agricultural Experiment Station Kansas State University Texas Tech University University of Nebraska Colorado State University NRCS Industry	measure temporal changes in soil and hydraulic properties in response to changes in management at field and landscape scales. **Product Users:** Producers, Extension and Private Sector Consultants, Conservation Districts, Natural Resources Conservation Service, Agricultural Industry, and the Scientific Community.	

Problem Area 3: Soil Carbon Measurement, Dynamics, and Management

Problem Statement

Rationale: Soil carbon usually comprises only a small fraction of the total soil mass, but it is a critical component that affects productivity and environmental quality. The dynamic properties of soil organic matter and many inorganic carbon compounds exert a significant influence on physical, chemical, and biological properties and processes such as soil structure, soil erodibility, nutrient availability, water infiltration and availability, and pesticide transformations. A better understanding of soil carbon dynamics is needed to improve management for sustainability.

Estimates indicate that each year in the U.S. about 1.33 billion tons of carbon are removed from the atmosphere as carbon dioxide by the photosynthetic activity of agricultural crops. Furthermore, indications are that the North American continent is potentially a large repository for carbon.

Research Needs: There is a need to provide information to agricultural producers, extension educators, NRCS personnel, policy makers, and scientists about management effects on soil carbon within different regions in the U.S. Improved understanding of soil carbon dynamics, as it relates to: the cycling of critical nutrients important to plant growth, soil structure, water relations, chemical (e.g., pesticide) retention and transformation is needed. Furthermore, there is a need to develop measurement tools for improved and more rapid quantification of soil carbon pools for use in production-oriented as well as research settings. Models are needed to predict soil carbon storage potentials over similar land management areas from field to regional and national scales. This information can then be used to increase our understanding of management effects on soil carbon dynamics and to develop improved management practices that increase soil C sequestration. This information will become increasingly important as policies to reward producers for carbon storage are developed. These three research themes – carbon measurement, carbon dynamics and carbon management – are the foci for this problem area.

Focus Area 1: Measurement tools for soil carbon. Critical to determining soil carbon dynamics and storage is the ability to measure soil carbon content and validate changes to that content over time. Adequate measurement of changes in soil carbon must include evaluation of the physical, biological, and chemical characteristics of soil organic matter and soil inorganic carbon. In addition, the stability of various physical and chemical components of soil organic matter needs to be evaluated. Measurement of changes in soil carbon must include sampling schemes that address the spatial and temporal variability of soil carbon; soil bulk density (weight per volume); and chemical, physical, and biological soil properties. Rapid analytical and field surveillance methods will extend our capability to predict soil carbon storage and changes in soil carbon.

Focus Area 1: Measurement Tools for Soil Carbon

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Co-Leaders: **Beltsville, MD:** Reeves (NP206), Daughtry **West Lafayette, IN:** Stott **Product Participants:** Akron, CO Ames, IA Beltsville, MD Columbia, MO Canal Point, FL Lubbock, TX **Cooperators** Agriculture and Agri-Food Canada Natural Resource Ecology Laboratory Colorado State University University of Manitoba University of Toronto University of Limerick (Ireland) University of Florida	1. Methods for the determination of carbon forms/pools in soil including: rapid spectroscopic methods, sensitive biochemical methods, large-scale remote sensing methods, methods for organic matter oxidation in Histosols, and organic matter extraction techniques **Product Users** NRCS and other Federal Agencies Commodity Brokers Agricultural Consultants Extension Agents Soil Testing Laboratories, Scientists.	**Short-term:** Better characterization of how, where and when soil carbon pools change. **Long-term:** Accurate quantification of soil carbon pools for use in production-oriented and research settings.

Focus Area 2: Soil carbon dynamics. A better understanding of soil carbon dynamics is needed to develop improved management strategies. The amount of carbon stored in soil is determined by the balance of two processes (1) production of organic matter by terrestrial vegetation (photosynthesis) and (2) decomposition of organic matter by soil organisms (respiration). Each of these processes is controlled by physical and biological factors. For a given plant type, photosynthetic production depends largely on climate (solar radiation, temperature, rainfall), soil water status, nutrient availability, and carbon dioxide concentration. Decomposition and soil carbon status is dependent upon some of these same variables (temperature, soil water, nutrient availability) as well as soil biological composition and activity, soil texture and mineral and organic composition. Interactions among these variables need to be better characterized to improve our understanding of soil carbon dynamics.

Focus Area 2: Soil Carbon Dynamics

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Leader: **Watkinsville, GA:** Franzluebbers **Product Participants:** Akron, CO Ames, IA Beaver, WV Beltsville, MD Canal Point, FL Morris, MN Pullman, WA **Cooperators:** **Within ARS:** Ft. Collins, CO Lubbock, TX Mandan, ND Morris, MN Pendleton, OR Sidney, MT West Lafayette, IN **Outside ARS:** University of Minnesota University of Florida	Synthesis publications documenting relationships of soil carbon pools with crop productivity, soil properties (e.g., clay and nutrient contents, microbial diversity) and processes (erosion, leaching).	**Short-term:** Improved management practices that retain a greater proportion of fixed carbon in soil. **Long-term:** Improved knowledge of how carbon dynamics affects nutrient cycling and soil organic matter transformations.

Focus Area 3: Effects of management on soil carbon. A portion of the fixed carbon within plants ultimately enters the soil, but the capacity of soils to store carbon, the length of time the carbon can be stored in the soil, and the rate at which carbon storage could be accomplished are matters of great interest to both scientists and policymakers. Because of the large historical loss, there is no doubt that soil can serve as a carbon repository. Scientific studies have shown that proper management practices such as conservation tillage, cropping intensity, fertilization, and water and manure management can increase soil carbon levels. Systematic methodologies to determine the impact of land use and management practices on soil carbon transformations and storage are needed to predict actual and potential soil carbon storage at local, regional, national, and global scales.

Focus Area 3: Effects of Management on Soil Carbon

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Leader: **Ft. Collins, CO:** Follett **Product Participants:** Canal Point, FL Ft. Collins, CO Kimberly, ID Lincoln, NE	Synthesis publications outlining region-specific management strategies to enhance carbon sequestration and minimize carbon loss. (Will be developed in conjunction with GRACEnet.)	**Short-term:** Improved management recommendations to enhance carbon sequestration and practices in croplands and grazing lands throughout the U.S.

Mandan, ND Morris, MN Pendleton, OR Watkinsville, GA West Lafayette, IN **Cooperators:** **Within ARS:** Ft. Collins, CO		**Long-term:** Enhanced soil carbon sequestration and reduced soil carbon losses from agroecosystems, resulting in improved soil quality, increased productivity and improved environmental quality.

Cross-Location Project: Greenhouse gas **r**eduction through **a**gricultural **c**arbon **e**nhancement **net**work **(**GRACEnet) is a cross-location research project. It is not a problem area in the Soil Resource Management National Program and is, in fact, primarily coded to the Global Change National Program. However, research within the GRACEnet project is closely related to research within the Soil Carbon Problem Area.

Rationale: Global climate change is a continuously occurring natural process that currently appears to be being strongly influenced by human activities including agriculture. The human influence is primarily from activities that increase atmospheric concentrations of greenhouse gases, in particular carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Agriculture contributes about 20% of the world's global radiation forcing from CO_2, CH_4, and N_2O. Agriculture produces 50% of the methane and 70% of the nitrous oxide of the human-induced emission of these gases. However, changes in management including minimizing or eliminating tillage; adding organic matter via cover crops and manure; improving nitrogen management for enhanced efficiency as well as other practices can convert agriculture from a net source to a net sink of greenhouse gases. Recent estimates indicate that U.S. soils have the potential to sequester 220 Tg C y^{-1}. There is increasing interest among farmers, ranchers, other land managers, policy makers, greenhouse gas emitting entities, and carbon (C) brokers in using agricultural lands to sequester C and reduce the emissions of CO_2, CH_4, and N_2O.

Research Needs: Precise information is lacking on how specific management practices in different regions of the country impact soil C sequestration and the mitigation of greenhouse gas emissions. This information is a prerequisite for the widespread adoption of C credit trading. Furthermore, this information, which will likely be region-specific in the U.S., needs to be generated and summarized. In addition, efforts to inventory current agricultural emissions and predict future emissions through the application of mathematical models will require additional data. The GRACEnet project represents a coordinated effort by the Agricultural Research Service to provide information on soil C status and greenhouse gas emissions of current agricultural practices, and to develop new management practices to reduce net greenhouse gas emissions and increase soil C sequestration primarily from soil management.

Cross-location Project: GRACEnet

Inputs/Resources Locations	Outputs/Products	Outcomes
Akron, CO Ames IA Auburn, AL Beaver, WV Beltsville, MD -SASL Beltsville, MD –HRSL	1. A national database of greenhouse gas flux and C storage. 2. Regional and national guidelines of management	**Short-term:** Assessment of agriculture's role as a source or a sink in greenhouse gas emissions. Enhance long-term soil

Inputs/Resources Locations	Outputs/Products	Outcomes
Beltsville, MD –CS&GCL Brookings, SD Canal Point, Fl Florence, SC Fort Collins, CO -SPNR Fort Collins, CO - RRRU Gainesville, FL Kimberly, ID Lincoln, NE Lubbock, TX Mandan, ND Morris, MN Orono, MA Prosser, WA Pendelton, OR Maricopa, AZ Pullman, WA Sidney, MT St. Paul, MN Temple, TX Tifton, GA Tuscon, AZ University Park, PA Watkinsville, GA West Lafayette, IN Wyndmoor, PA	practices (in the form of decision aid) that reduce greenhouse gas intensity; applicable for use by producers, federal and state agencies, and C brokers. 3. Development and evaluation (e.g., IPCC) of computer models created to assess management effects on net greenhouse gas emissions. 4. Summary paper for action agencies and policy makers, based on the current state of knowledge.	productivity because of reduced tillage, organic matter additions and other practices that increase soil organic matter and reduce soil erosion, improve water-holding capacity and improve nutrient cycling. **Long-term:** Optimize carbon sequestration on agricultural land, while maintaining economic viability and enhancing environmental quality. Agricultural management systems that foster carbon storage in soil and reduce emissions of methane and nitrous oxide.

Problem Area 4: Nutrient Management for Crop Production and Environmental Protection

Problem Statement

Rationale: Inorganic and organic nutrient sources play an essential role in meeting the food and fiber demands of a growing world population. Inefficient nutrient use results in an economic loss to producers and creates an environmental risk to the public. Fertilizer use-efficiency is commonly less than 50% in many agricultural systems. Application of excessive amounts of fertilizer and manure contribute to agriculture being the largest non-point source of pollution to surface and groundwater. Two important nutrients, nitrogen (N) and phosphorus (P), have divergent flow paths from point of application to edge-of-field, as well as, to and in streams. A better understanding of N and P transport and fate, as well as that for other nutrients essential for plant growth will be needed to develop more effective and efficient nutrient management practices.

Research Needs: Research is needed to understand nutrient fate and transformations in soil so management practices can be developed for sustainable production while protecting soil, water, and air. Improved nutrient management strategies for producers are needed for optimizing agricultural inputs and productivity and for making informed regulatory policy. Producers, consultants, policy makers, and others involved in nutrient management will benefit from improved decision support tools for nutrient management. Although much is already known about nutrient fate and transport, our knowledge is incomplete; therefore, decision support tools describing nutrient fate and transport need to be greatly improved.

Focus Area 1: Decision support tools for improved nutrient management. Research in this area will result in the development of tools for improved nutrient management that incorporate biological, chemical, and physical properties and processes. These decision support tools range from fact sheets and guidelines to computer based decision support systems.

Focus Area 1: Decision Support Tools for Improved Nutrient Management

Inputs/Resources **Locations**	**Outputs/Products**	**Outcomes**
	1.Decision support information (publications) and tools for enabling customers to use nutrients effectively.	**Short-term:** Producers and advisors can select appropriate strategies for effective use of nutrients.
1a. Product Co-leaders: **Columbia, MO:** Kitchen **Lincoln, NE:** Shanahan **Product Participants:** Beltsville, MD Columbia, MO Lincoln, NE: Pullman, WA Temple, TX	a. Algorithms for improved in season N management.	**Long-term:** Less N loss and more effective plant utilization of N.
1b. Product Leader: **Beltsville, MD:** Daughtry **Product Participants:** Auburn, AL Beltsville, MD Brookings, SD Lincoln, NE	b. Measurement tools for nutrient management.	
1c. Product Leader: **Ft. Collins, CO:** Follett **Product Participants:** Ft. Collins, CO	c. Improved NLEAP model to transfer to NRCS	
1d. Product Co-leaders: **Beltsville, MD:** Meisinger **Lincoln, NE:** Schepers **Product Participants:** Auburn, AL Ft. Collins, CO Orono, ME Prosser, WA St. Paul, MN Sidney, MT	d. N-Index, a decision aid for identifying and selecting cultural and management practices to protect surface and ground water from N contamination.	

Inputs/Resources Locations	Outputs/Products	Outcomes
University Park, PA **Cooperators:** **Within ARS:** Watkinsville, GA **Outside ARS:** Colorado State Univ NRCS		
1e. Product Leader: **Ames, IA:** Kovar **Product Participants:** Beaver, WV Beltsville, MD West Lafayette, IN Watkinsville, GA **Cooperators:** **Outside ARS:** University of Georgia Georgia Extension NRCS	e. Synthesis publications and guidelines on phosphorus management.	
1f. Product Leader: **Akron, CO:** Vigil **Product Participants:** Akron, CO Auburn, AL Kimberly, ID St. Paul, MN Watkinsville, GA **Cooperators:** **Within ARS:** Ames, IA Dubois, ID Logan, UT Madison, WI **Outside ARS:** Auburn, University South Dakota State University University of Wisconsin Agriculture and Agri-Food Canada Farmsite Technologies: Quinn Nuclear Regulatory Commission	1f. Guidelines and fact sheets for better nutrient management. **Product Users:** Producers, Agricultural Consultants, Industry, Regulatory Agencies, and NRCS.	

Inputs/Resources Locations	Outputs/Products	Outcomes
PVI Victoria Australia Simplot Spec TIR		

Focus Area 2: Management practices and strategies for increasing nutrient use efficiency. A crop usually takes up less than 50% of the nutrients added from fertilizers within the season of application. This level of nutrient use efficiency is caused by the myriad of interactions among nutrients and soil constituents, nutrient transformations mediated by soil biology and chemistry, as well as leaching and runoff. Some of these transformations cannot be avoided and, in fact, are necessary for life sustaining nutrient cycling. Modifying current practices and developing new practices that emphasize efficiency can decrease losses from the root zone.

Focus Area 2: Management Practices and Strategies for Increasing Nutrient Use Efficiency

Inputs/Resources Locations	Outputs/Products	Outcomes
	2.Alternative management practices and strategies for increasing nutrient use efficiency described in synthesis and scientific publications, guidelines, fact sheets and/or decision support tools for:	**Short-term:** More economically sound crop production. **Long-term:** Improved water quality and more fertile soils.
2a. Product Leader: **Fort Collins, CO:** Halvorson **Product Participants:** Ames, IA Saint Paul, MN	a. Irrigated agriculture	
2b. Product Leader: **Akron, CO:** Vigil **Product Participants:** Akron, CO Auburn, AL Brookings, SD Saint Paul, MN Pendleton, OR Pullman, WA West Lafayette, IN **Cooperators:** **Outside ARS:** Auburn University Colorado State Univ. Minnesota Department of Agriculture Montgomery	b. Rainfed agriculture **Product Users:** Producers, Agricultural Consultants, Industry, Regulatory Agencies, and NRCS.	

Inputs/Resources Locations	Outputs/Products	Outcomes
Montana State Univ. North Carolina State University NRCS Nuclear Regulatory Commission Oregon State Univ. Petrie Plainview Farms Spec TIR South Dakota State Univ. University of Arkansas University of California-Riverside University of Georgia University of Minnesota Rosen, Engel, Kumar University of Wisconsin Kung Washington State University		

Problem Area 5: Adoption and Implementation of Soil and Water Conservation Practices and Systems

Problem Statement
Rationale: The soil resource supports sustainable food and fiber production and contributes to a healthy environment. However, soil is not "indestructible and immutable", but requires improved management for conservation. Innovative solutions to conserve the soil resource through improved management strategies will be needed to meet agricultural and societal demands for greater production and environmental quality protection.

Producers and other land managers need tools to evaluate the effect of their management practices on soil, air, and water resource as well as on crop productivity. Tools, such as the NRCS Soil Conditioning Index (SCI) and the Soil Management Assessment Framework (SMAF) are being developed to aid in this holistic assessment. These and other decision aids and tools (e.g., determination of management zones for site specific or precision agriculture) need further development and evaluation to increase their robustness, reliability, and ultimately their use in guiding management decisions.

Research Needs: There is a need to provide producers, advisors, and policy makers with improved conservation practices and systems. The overall objective of this problem area is to overcome barriers that limit implementation of conservation practices and systems. Many conservation practices and systems require further investigation and improvement so they can be used in unique or dynamic production applications. Therefore, research in this problem area will also emphasize continued development of residue management practices, crop rotations, cover crops, and integrated crop livestock production to meet the soil conservation needs of the 21st century. Tools to evaluate and determine the impacts of management practices on the soil resource need to be developed and tested. Tools to measure and predict the environmental benefits of conservation practices and systems need to be developed.

Focus Area 1: Improved knowledge and technologies to expand the development and use of new conservation systems. The adoption of conservation practices has leveled off in many regions of the U.S. limiting sustainable production and increasing soil and environmental degradation. Barriers to the use of conservation practices, such as plant establishment, pest control, equipment use need to be evaluated and research initiated to overcome these limitations. Greater emphasis needs to be on: (1) cold, wet soils, (2) irrigated soils, (3) semi-arid soils and (4) regions with low adoption of conservation practices. Where appropriate, new production systems will be developed. This program will emphasize crop sequences and rotations, including cover crop management and inter-cropping and management practices for integrated crop-livestock systems. The diversity of climates and crops requires regional specificity, which precludes the application of uniform management practices or experimental protocols across the country.

Focus Area 1: Improved knowledge and technologies to expand the development and use of new conservation systems.

Inputs/Resources Locations	**Outputs/Products**	**Outcomes**
1a. Product Co-Leaders: **Auburn, AL:** Raper **Brookings, SD:** Osborne **Product Participants:** **Ames, IA** Akron, CO Auburn, AL Bushland, TX Ft. Collins, CO Pendleton, OR St. Paul, MN **Cooperators:** South Dakota No-Till Assoc. South Dakota State Univ. Univ. Minnesota Minnesota Corn Growers Assoc. Univ. Neb. Lincoln Alabama Agric. Exp. Stn. Alabama Agric. Ext. Serv. Auburn Univ. Louisiana Agric. Exp. Stn., Texas Agric. Exp. Stn. Texas Coop. Ext. CTIC Oregon State Univ. Washington State Univ. Colorado State Univ. Kansas State Univ.	1a. Fact sheets, management guides, and synthesis publications that focus on conservation tillage technologies for cold, wet soils; irrigated soils; semi-arid dryland soils; and temperate non-irrigated soils. **Product Users:** Producers, Ag Consultants, Industry, Extension, NRCS, Non-profit Ag. organizations, policy makers (government), NRD's, Conservation Districts, University and other scientists.	**Short term**: Measurable increase (20%) in implementation of conservation practices on susceptible soils. **Long term**: Conservation practices implemented on the majority of susceptible soils.

Inputs/Resources Locations	Outputs/Products	Outcomes
1b. Product Co-Leaders: **Bushland, TX:** Baumhardt **Watkinsville, GA:** Schomberg **Product Participants:** Akron, CO Auburn, AL Brookings, SD Bushland, TX Ft. Collins, CO Lincoln, NE Lubbock, TX Mandan, ND St. Paul, MN Watkinsville, GA **Cooperators:** Alabama Agric. Exp. Stn. Alabama Agric. Ext. Serv. Auburn Univ. Univ. Georgia Univ. Neb. Lincoln South Dakota No-Till Assoc. South Dakota State Univ. Univ. Minnesota Texas Agric. Exp. Stn., Texas Coop. Ext. Colorado State Univ. Kansas State Univ.	Fact sheets, management guides, and synthesis publications that focus on conservation cropping systems (including cover crops and inter-cropping) and practices for integrated crop-livestock systems. . **Product Users:** Producers, NRCS, Ag Consultants, Extension, and other scientists.	**Short term:** Measurable increase (20%) in implementation of improved crop sequences, rotations, & integrated crop-livestock systems. **Long term:** Conservation cropping sequences, rotations, and integrated crop-livestock systems implemented on the majority of all susceptible soils.

Focus Area 2: Decision tools to assess benefits and enhance adoption of conservation practices and systems. Beneficial effects of conservation practices on soil properties are usually known for erosion control or a few properties such as soil strength and compaction, but not for a suite of physical, chemical and biological indicators. However, for conservation programs such as the Conservation Security Program (CSP) producers and other land managers now need to evaluate the effect of their management practices on soil, air, and water quality as well as crop productivity. Tools, such as the NRCS SCI and the SMAF are being used and developed to aid in this holistic assessment. These and other decision aids and tools (e.g., within field management zones for site specific or precision agriculture) need further testing, evaluation and development to increase their robustness, reliability and ultimately their use in guiding soil and crop management decisions.

Focus Area 2: Decision tools to assess benefits and enhance adoption of conservation practices and systems.

Inputs/Resources Locations	Outputs/Products	Outcomes
2a. Product Co-Leaders: **Ames, IA:** Karlen **Lincoln, NE**: Wienhold **Lubbock, TX:** Zobeck **Product Participants:** Akron, CO Ames, IA Auburn, AL El Reno, OK Ft. Collins, CO West Lafayette, IN Lincoln, NE Mandan, ND Pendleton, OR Pullman, WA Tifton, GA Temple, TX **Cooperators:** NRCS-Greensboro, NC. Univ. Neb. Lincoln Alabama Agric. Exp. Stn. Alabama Agric. Ext. Serv. Auburn Univ. Texas Agric. Exp. Stn. Texas Tech Univ. NRCS-Lubbock, TX, Temple, TX Agric Exp. Stn., Tribune, KS	2a. Assessment tools to quantify soil quality benefits from conservation practices and systems. Specific products will include: (a) comparison of the SCI and the Soil Management Assessment Frame and (b) the development of additional scoring curves for inclusion in the SMAF. **Product Users:** NRCS, Universities, Producers, Extension, Ag Consultants, policy makers (government), and other scientists.	**Short term:** Assessment tools are available to implement and promote conservation strategies. **Long term:** Conservation practices are implemented on the majority of susceptible soils.
2b. Product Leader: **Beltsville, MD:** Gish **Product Participants:** Akron, CO Auburn, AL Beltsville, MD Columbia, MO Lincoln, NE Morris, MN Pullman, WA Riverside, CA Watkinsville, GA **Cooperators:** Univ. Neb. Lincoln Alabama Agric. Exp. Stn. Alabama Agric. Ext. Serv. Auburn Univ.	2b. Tools to delineate management zones for profitable adaptation of conservation practices and systems within fields. **Product Users:** Producers, Industry, Ag Consultants, Extension, NRCS	

Inputs/Resources Locations	Outputs/Products	Outcomes
Kansas State Univ. Colorado State Univ. Univ. of Nebraska		

Problem Area 6: Impact on Soil of Residue Removal for Biofuel Production

Problem Statement

Rationale: Domestic ethanol production is a strategy to reduce dependence on imported energy and to reduce emission of greenhouse gases from use of fossil-energy derived motor vehicle fuel. The Federal government is encouraging increased use of ethanol, and some states (e.g., Minnesota) require a specific, and increasing, percentage of ethanol use in fuel. Over 99% of current U.S. ethanol production is from fermented grains. Greater use of grain as a feedstock for ethanol, though desirable from a farm income viewpoint, increases ethanol production costs and exacerbates the narrow margin fuel ethanol producers experience in a market controlled by the price of gasoline. It also places energy production in competition with food production for grain supplies. In the 1990s U.S. Department of Energy (DOE) and private industry rekindled efforts to use a wider array of agriculture products as sources of renewable energy. Initially these efforts focused on energy crops, short-rotation poplar and switchgrass; both requiring development of new technology to efficiently convert biomass to ethanol. The DOE has an ambitious program to develop and market the necessary technology. More recently crop residues, especially corn stover, have been identified as a source of cellulosic biomass available in sufficient quantities and concentration to meet needs of the proposed processing plants, biorefineries. Biofuel and bio-product proponents view crop residues as an under-utilized resource. Current proposals assume crop residues remaining in the field could be collected for fuel production at little or no economic, environmental, or sustainability costs.

Research Needs: Though it may appear that crop residues are not used in modern grain production systems, this perception is far from the truth. Crop residues (above and below ground) are the major source of organic matter returned to the soil, replenishing (if only partially) that lost through crop culture. Research over the past century has conclusively shown that crop cultural practices result in loss of soil organic matter (SOM). In addition, research on soil health conducted by ARS and other groups, has shown that SOM and the cycling of organic matter is responsible, at least in part, for many favorable attributes of productive soils. Limited research has shown residue removal reduces yield of both grain and stover of subsequent crops and further lowers SOM levels. Crop producers, biomass ethanol producers, and action agencies need knowledge and guidelines, based on current yield potentials and production practices, to determine the amount of crop residue that must remain on the soil to prevent loss of production capacity and soil functionality.

Problem Area 6: Impact on Soil of Residue Removal for Biofuel Production

Inputs/Resources Locations	Outputs/Products	Outcomes
Product Leader: **Lincoln, NE**: Wilhelm **Product Participants:** Ames, IA Auburn, AL	1.Guidelines for management practices supporting sustainable harvest of residue.	Bioenergy and bio-product production systems that significantly contribute to US energy independence, reduce greenhouse gas emissions, and support rural communities

Inputs/Resources Locations	Outputs/Products	Outcomes
Brookings, SD Ft. Collins, CO Lincoln, NE Morris, MN Pendleton, OR St. Paul, MN West Lafayette, IN **Cooperators:** **Within ARS:** Lincoln, NE Morris, MN Pendleton, OR West Lafayette, IN **Outside ARS:** Minnesota Corn Growers NRCS NREL University of Minnesota DOE-INL	2. Algorithm(s) estimating the amount of crop residue that can be sustainably harvested. 3. Decision support tool and guidelines describing the economic trade-off between residue harvest and retention to sequester soil C.	without degrading soil resources.

Problem Area 7: Managing Pesticides in Soils

Problem Statement

Rationale: Pesticides are a diverse group of chemicals whose principal use is to improve crop production. These compounds are an integral component of modern agriculture; however, their use can result in contamination of soil, water and air resources. Widespread adoption of integrated pest management programs and advances in biotechnology have the potential to reduce pesticide use in some settings; but to date they have not reduced farmer demands for products which can be applied to fields to control plant diseases and weed and insect infestations. There is consensus that widespread use of pesticides to meet food and fiber needs worldwide will continue into the foreseeable future. This creates a continuing need for development and evaluation of pesticide management strategies that maintain efficacy of pest control, while minimizing risks to human health and the environment. Quantifying pesticide fate and behavior in soil environments is central to this task.

Research Needs: One of the principal functions of soil when used for crop production is the retention and degradation of agricultural chemicals, in particular pesticides. How efficiently soil performs this function determines both pest control efficacy and potential for adverse environmental impact. Decades of research have provided a general understanding of soil processes that control pesticide behavior; however, the knowledge base remains incomplete. To manage pesticides effectively and more accurately assess risks and benefits of their use, further insight is needed which reflects both the diversity of pesticide properties, and crop, soil, and climatic conditions under which they are used. Information is needed for products in current use and new pesticides as they enter the market. Key topic areas include sorption and desorption, degradation and transformation, interactions of these processes, and how soil microbial communities adapt and or are impacted by repeated pesticide applications. Increasing use of conservation management systems such as reduced tillage, cover crops, and filter strips requires targeted research on how pesticide fate in soil may be affected. Evaluation of the spatial and temporal variability of factors that influence pesticide fate and efficacy in soil is a companion need since in the future pesticide application will likely include site-specific technology. The planned research will help underpin the development of management practices to optimize pesticide performance, maintain the sustainability of soil resources, and minimize environmental impacts.

Problem Area 7: Managing Pesticides in Soils

Inputs/Resources Locations	**Outputs/Products**	**Outcomes**
1. Product Co-Leaders: **Stoneville, MS:** Zablotowicz **Tifton, GA:** Potter **Product Participants:** Akron, CO Columbia, MO Ft. Collins, CO Morris, MN St. Paul, MN Stoneville, MS Tifton, GA Urbana, IL West Lafayette, IN **2. Product Leader:** **Stoneville, MS**: Kurtz **Tifton, GA:** Potter **Product Participants:** Akron, CO Ames, IA Columbia, MO Morris, MN Stoneville, MS Tifton, GA Urbana, IL West Lafayette, IN **3. Product Leader:** **Stoneville, MS:** Zablotowicz **Product Participants:** Columbia, MO Stoneville, MS St. Paul, MN **Cooperators:** **Within ARS:** Beltsville, MD Ft Collins: CO Oxford, MS	1.Synthesis publications and guidelines describing the influence of soil and pesticide properties, climatic conditions and cropping systems on pesticide persistence including sorption and degradation. (This area includes a multi-location examination of field and laboratory dissipation of a widely used pesticide.) 2. Synthesis publications and guidelines quantifying the influence of conservation practices in particular reduced tillage, cover crops, and vegetated filter strips on pesticide fate, transport, and efficacy. 3. Synthesis publications and guidelines on impacts of transgenic BT, and herbicide-resistant cropping systems on soil-plant-microbial interactions. **Product Users:** EPA and state environmental regulatory agencies, the agrochemical industry, extension personnel and consultants, land grant university researchers, and non-governmental organizations	Improve the scientific basis for mitigating risks of agricultural pesticide use while maintaining pest-management efficacy

Inputs/Resources Locations	Outputs/Products	Outcomes
Outside ARS: W-45, W-82, S-1011 Univ. Illinois Iowa State Univ. Purdue Univ. Michigan State Univ. Texas A&M Univ. Univ. Georgia Univ. Florida	that promote sustainable agricultural production	

Problem Area 8: Control of Soil Erosion

Problem Statement

Rationale: Soil erosion, sediment movement, and depositional processes are a function of the interactions between water, wind, and gravity with the level of intensity determined by landscape and soil characteristics, and vegetative cover. Soil erosion continues to be the principal threat to the long-term sustainability of US agriculture. It is estimated that over 2 billion tons of soil per year are lost from US cropland because of rain- and wind-induced erosion. Soil erosion control is essential for sustainable agricultural production systems because erosion affects soil properties progressively over time and generally diminishes soil quality and resistance of agricultural systems to stresses.

Research Needs: Improved technologies are required for conserving soil, enhancing soil quality, and reducing off-site impacts. Information needs to be developed concerning the effects of amending, modifying, and managing soils on the susceptibility of soils to erode in space and time. The basic focus in this problem area will be erosion control practices and technologies. Research activities in the overall ARS erosion program are given in the second Table and include contributions from the water, soil, and air programs. The ARS Soil Erosion and Sedimentation program is described (listed with Inputs/Resources, Locations) within the NP 201 Action Plan.

Problem Area 8: Control of Soil Erosion

Inputs/Resources Locations	Outputs/Products	Outcomes
1. Product Co-Leaders: **Kimberly, ID:** Lentz **Oxford, MS:** Rhoton **Product Participants:** Kimberly, ID Oxford, MS Pullman, WA Tifton, GA West Lafayette, IN	1. Management practices, amendments (e.g., PAM, gypsum) and technologies to control erosion induced by irrigation, rainfall, and tillage.	Reduced soil erosion for improved food security
2. Product Leader: **Lubbock, TX:** Zobeck **Product Participants** Manhattan, KS	2. Guidelines for predicting dust emissions, threshold velocity, and plant damage for wind erosion as a function of soil properties and management	

St. Paul Pullman, WA		

Overall Soil Erosion and Sedimentation Research

Outputs/Products	Outcomes
1. Database and predictive relationships for erosion and sediment transport caused by concentrated flow in irrigation furrows, ephemeral gullies, and edge-of-field gullies	**Short term** Predictive ability and databases will allow improved estimation of concentrated flow erosion from selected sites. (Product 1) **Long term** Robust predictive ability and comprehensive database will provide reliable estimation of erosion and sediment transport caused by concentrated flow.
2. Decision support tools and databases for sediment loads, yields, and off-site impacts considering fractional sediment transport and deposition, geomorphic aspects of stream evolution, and reservoir/pond sedimentation for purposes of quantifying landscape scale erosion rates	**Short term** Intermediate gains will increase ability to quantify landscape scale erosion. (Product 2) **Long term** Ability to quantify landscape scale erosion and off-site impacts will be enhanced.
3. Guidelines for reducing the risk of dam breaching and subsequent failure using analyses of dam-breach failures and processes triggered by concentrated flow action	**Short term** Improved predictive and preventive capabilities with regard to dam breach will be achieved. (Product 3) **Long term** Ability to predict performance of existing structures and ability to improve designs based on simulation will be demonstrated.
4. Improved tool for assessment of soil susceptibility to erosion including spatial, temporal, topographical, vegetative, and management effects	**Short term** Improved assessment of how climate, topography, and management affect erodibility and threshold velocities will lead to improved management systems and more reliable modeling of conservation effects at select locations. (Product 4) **Long term** Improved assessment of how climate, topography, and management affect erodibility and threshold velocities will lead to improved management systems and more reliable modeling of conservation effects nationally.
5. Best Management Practices and design tools for in-field erosion control; gully and ephemeral channel erosion prevention; riparian corridor stabilization; and sediment retention structures	**Short term** Design tools and practices for erosion prevention, water infrastructure improvements, and riparian corridor management will be developed that will

Outputs/Products	Outcomes
	reduce sediment losses from fields and streams. (Product 5) **Long term** Improved conservation practices will be developed for reducing sediment losses reduce sediment losses from fields, streams to lakes, and rivers.
6. Multi-scale model to predict wind, water, and tillage erosion, and downstream impact of sediment movement on agricultural landscapes using a common interface with shared databases: development, parameterization, and validation **Product Users** Producers, NRCS, USFS, USGS, EPA, universities, soil and water conservation districts, State planning boards, farmers, ranchers, engineers, and consultants	**Short term** Integration of existing field-scale water, wind, and tillage erosion models will be facilitate conservation planning on agricultural lands. (Product 6) Improved predictions of winter erosion processes, irrigation-induced erosion, rangeland hydrology and erosion, tillage erosion, and wind erosion threshold velocities and dust emissions will improve resource protection. (Product 6) **Long term** Comprehensive decision support systems that integrate water erosion, wind erosion, tillage erosion, and sedimentation predictions will improve long-term conservation planning and impact assessments.

Problem Area 9: Remediation of Degraded Soils

Problem Statement

Rationale: Soil degradation, either through human activities or natural forces, is often initiated by the processes of accelerated soil erosion, loss of vegetative cover, and oxidation of soil organic matter, which lead to the impairment of soil physical, chemical and biological properties and processes, and eventually to reduced soil productivity and damaged ecosystems. On a worldwide basis, a major cause of soil degradation and environmental concern is water, wind, tillage, and irrigation-induced erosion. Similarly, poor land management can cause: a loss of soil organic matter; soil compaction; accelerated soil acidification; and a buildup of salts, toxic elements and nutrients. Effective and economically feasible management practices are needed to prevent soil degradation and to remediate degraded soils.

Research Needs: Producers, advisors, and policy makers need guidelines for remediating degraded soils. The overall goal of this problem area is to ensure that degraded soils become productive and sustainable to maintain food security and safety and to no longer impair environmental quality. The targets of this research will be development of management practices, guidelines and assessment tools to address soil erosion, compaction, trace element contamination and salinity.

Problem Area 9: Remediation of Degraded Soils

Inputs/Resources Locations	Outputs/Products	Outcomes
1. Product Leader: **Florence, SC:** Busscher **Product Participants:** Akron, CO Auburn, AL Bushland, TX Riverside, CA	1.Management practices and guidelines to correct soil compaction and poor soil structure/aggregate stability.	Degraded soils become more productive and less likely to contribute to contamination of water and air.
2. Product Leader: **Florence, SC:** Novak **Product Participants:** Beaver, WV Beltsville, MD Ft. Collins, CO Oxford, MS Kimberly, ID Riverside, CA	2. Remediation techniques and amendments to remove or sequester trace elements, excess nutrients, or other contaminants in soil.	
3. Product Leader: **Riverside, CA:** Corwin **Cooperators:** Westlake Farms University of California – Davis	3. Techniques and guidelines to map, monitor, and remediate saline soils and to spatio-temporally access their quality. **Product Users:** San Joaquin, Imperial, and Coachella Valley irrigation districts; NRCS; Bureau of Reclamation; Producers from the west side of the San Joaquin Valley	