USDA Agricultural Research Service National Program 212—Soil and Air Action Plan 2016-2020

USDA Agricultural Research Service

National Program 212
SOIL AND AIR

Action Plan 2016-2020

Goal: The goal of National Program (NP) 212 - Soil and Air, is to expand, maintain, enhance, and protect soil resources essential for U.S. agricultural production as well as to optimize the management of crop nutrients and greenhouse gas emissions (GHG) from agricultural soils and byproducts, and explore options for production management in the face of global climate change.

The National Program 212 research outlined in this Action Plan has been expanded to include the projects from the former National Program 214, Agricultural and Industrial Byproducts. The merger of these two National Programs will offer improved efficiency in use of available resources and stronger multidisciplinary cooperation for an improved, holistic approach by bringing together scientists from a wide variety of research fields into one stronger soil and air program.

The projects developed under this Action Plan will:

- Develop and improve management practices and stewardship strategies that protect beneficial biological, chemical, and physical soil properties, resulting in agriculturally versatile soil resources that are resilient to climate change and other environmental and management challenges;
- Develop and improve nutrient management practices that improve nutrient use efficiency; protect soil productivity; reduce off-site movement of reactive nitrogen, phosphorus, or other nutrients; protect air and water resources; and minimize human and environmental risks; and
- Develop and improve management practices and stewardship strategies to reduce soil pathogens and antibiotic resistance; reduce air and odor emissions from animal systems; reduce environmental risk of potential contaminants from cropping and post-harvest systems; and reduce the risk and develop beneficial uses of agricultural, municipal and industrial byproducts; to mitigate potential environmental risks related to agricultural practices.

The results of this research will help to:

- Ensure the availability of soil resources needed to provide food, feed, fiber, and feedstock for an expanding global population;
- Optimize management strategies and practices that protect biological, chemical, and physical soil characteristics and enhance overall soil health and productivity, especially in the face of drought, saline buildup, and other challenges that may be associated with climate change;
- Reduce the loss of nutrient amendments such as nitrogen and phosphorus from

agricultural landscapes;

- Minimize the release of particulate, odor-causing, volatile and greenhouse gas emissions;
- Optimize best management practices that reduce risks associated with pathogens, antibiotic resistant bacteria, and antibiotic resistance genes; and
- Develop uses for agricultural, industrial, and municipal byproducts, including manure.

Meeting the complex and dynamic challenges related to developing a sustainable, intensified agriculture requires a multi-location, multi-faceted, long-term approach. In addition to conducting single-site research projects, ARS scientists in this National Program participate in long-term, multi-location national research projects that include investigations into important biotic and abiotic factors in soil management and greenhouse gas emissions. Project partners include existing and emerging working groups and ARS networks [including REAP (ARS-Resilient Economical Agricultural Practices); CEAP (Conservation Effects Assessment Project); GRACEnet (Greenhouse gas Reduction through Agricultural Carbon Enhancement network); and Livestock GRACEnet] as well as groups from universities, the Cooperative Extension Service, private industry, other U.S. agencies, and national and international cooperators.

The long-term research approach in NP 212 will enable close cooperation and information sharing with scientists involved with the ARS Long-Term Agro-ecosystems Research (LTAR) network, the USDA Regional Biomass Research Centers, and the USDA Climate Hubs, which transfer information to help farmers, ranchers, and forest landowners adapt to climate change and weather variability. NP 212 research results will also be used to facilitate data synthesis and utilization in GRACEnet, REAP, and other ARS databases.

NP 212 has a broad range of stakeholders for whom the research in this National Program has significance, including Federal, State, and Local agencies; university researchers; producers and commodity groups; farmers, ranchers, and landholders; non-governmental organizations (such as the Nature Conservancy, Environmental Working Group, and Union of Concerned Scientists); and extension educators.

The research associated with the NP 212 Action Plan is grouped within three major research components:

1. Management and stewardship of soil resources;
2. Managing nutrients in agroecosystems; and
3. Reducing environmental risk of agricultural operations.

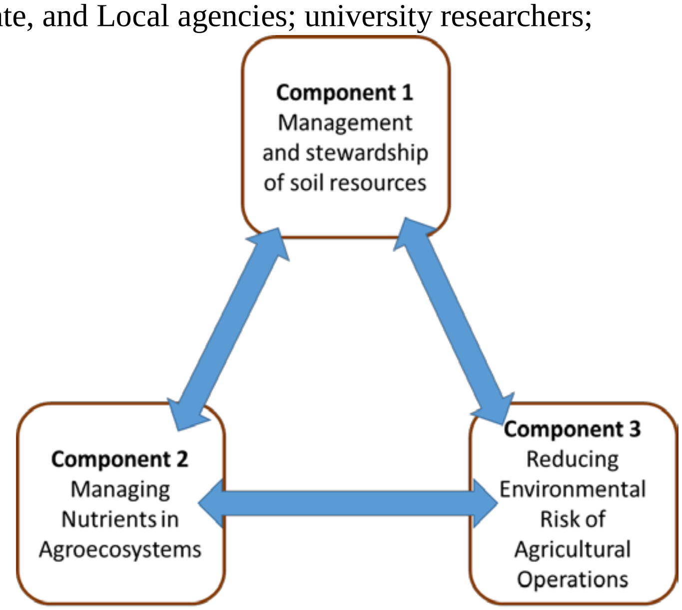

Figure 1: The three Components of the NP 212 Action Plan allow the sharing of resources and research to achieve goals.

To achieve the overall goals of NP 212, components of the research are large multidisciplinary efforts that involve collaborations with agricultural researchers conducting research in different components of this action plan (See Figure 1). For instance, soil health (component 1) is related to organic carbon sequestration, which contributes to improvements in soil chemical, physical and biological properties, and is also related to nutrient cycling (component 2) and reduction of the risk of potential contaminants (component 3).

It is not possible to carve out distinct research components with neat, sharp boundaries due to the interaction between soil and air resources within agroecosystems (Figure 1). Stewardship of soil resources, managing nutrients, and reducing environmental risk of agricultural operations are all closely related. For the purpose of this 5-year Action Plan, research on aspects of soil health other than those related to managing nutrients is generally contained in Component 1. Component 2 brings together all aspects of nutrient management to increase coordination across all projects that address the high priority, highly visible, nutrient management issues, such as reactive nitrogen. Component 3 focuses on research to reduce environmental and human health risks from agricultural operations, as well as developing beneficial agricultural uses for agricultural, industrial, and municipal byproducts. A project can include work in one, two, or all three components of NP 212.

Additionally, components of NP 212 research are multidisciplinary efforts that involve collaborations with agricultural researchers from other programs. Thus, NP 212 projects will complement research being conducted in several other ARS National Programs, including NP 107, Human Nutrition; NP 108, Food Safety; NP 211, Water Availability and Watershed Management; NP 213, Biorefining; NP 215, Pasture, Forages, and Rangeland Systems; NP 303, Plant Diseases; NP 304, Crop Protection and Quarantine; and NP 305, Crop Production. In addition, NP 212 projects will also complement research efforts being conducted in NP 216, Agricultural System Competitiveness and Sustainability, especially NP 216's new climate change adaptation projects in the area of Genetics by Environment by Management interactions (GxExM).

RELATIONSHIP TO THE ARS STRATEGIC PLAN

Outputs of NP 212 research support the Actionable Strategies associated with the performance measures listed below from the *ARS Strategic Plan for 2012 – 2017*, Strategic Goal Area 2: Natural Resources and Sustainable Agricultural Systems; Goal 2.2 – *Improve Quality of Atmosphere and Soil Resources, Understand Effects of Climate Change* and Goal 2.4 – *Effectively and Safely Manage and Use Manure and Other Agricultural and Industrial Byproducts In Ways That Maximize Their Potential Benefits While Protecting the Environment and Human and Animal Health. (http://www.ars.usda.gov/Aboutus/docs.htm?docid=1415).* This Action Plan also aligns with Goals 2A, *Responding to Climate Variability* and 3B *Landscape-Scale Conservation and Management* of the USDA Research, Education, and Economics Action Plan (February 2012).

COMPONENT 1: MANAGEMENT AND STEWARDSHIP OF SOIL RESOURCES

Healthy soil resources are key to agricultural productivity. Extreme climatic events (e.g., droughts, intensive precipitation, and higher and lower temperatures) are increasing in frequency and intensity, and adversely affect soil resources. Soil erosion by wind and water continues despite agricultural management to protect soil, while some tillage and the lack of cover cropping or cover residue contribute to off-site transport of soil particles. Soil compaction, soil acidification, and buildup of salts also contribute to soil degradation.

Increasing soil carbon sequestration improves soil organic matter, cation exchange capacity, aggregate stability, nutrient availability and water-holding capacity, all of which are essential for maintaining agricultural productivity. Management practices that help increase carbon sequestration also contribute to reduced wind and water erosion, help ameliorate and restore degraded soils, and could add to the strategies available to producers to adapt to climate change. Integrating findings about the physical, chemical, and biological properties of soils will improve efforts to measure, model, and manage soil resources. This information, in turn, will be essential for limiting soil degradation, mitigating greenhouse gas emissions, sequestering soil carbon, improving nutrient use and cycling, building resilience to climate change, and enhancing soil health and resilience. Long-term studies of practices and/or combinations of practices such as no-till production, cover cropping, manure amendments, composting, and agricultural byproduct management can contribute information needed to prevent soil degradation, and increase soil health and carbon sequestration. These practices will also be beneficial for soil biological properties that enhance soil sustainability and resilience.

New tools for research on soil microbiomes and soil ecosystems are revolutionizing the understanding of soil biology. These advances offer new opportunities to promote agroecosystem services that provide long-term sustainable protection of air, soil, and water quality; and improve crop production levels, quality, and safety. Additionally, remote sensing tools provide powerful tools for detecting and monitoring soil degradation and protecting soil resources.

Multi-location, multi-disciplinary scientific and engineering groups contributing to long-term projects, such as ARS REAP, GRACEnet, LTAR, and CEAP, have proven to be an effective way to foster collaborations. These efforts advance new production and conservation methods, the development of decision support technologies, the collection and stewardship of high quality data, and the development of critical scientific expertise for sustainable, long-term research.

Problem Statement 1A: *Preventing and ameliorating soil degradation*.

The intensification of agricultural systems requires implementing best management and conservation practices to avoid soil degradation and production losses. Accelerated erosion from wind and water, tillage erosion, soil acidification, and salt accumulation lead to soil degradation. This, in turn, reduces crop productivity, soil biological diversity, and soil resilience to extreme climatic events. It also increases on- and off-site environmental degradation and adverse human health impacts. These effects, singly and in combination, eventually result in unproductive, damaged agroecosystems. It is imperative to develop and implement suitable conservation and best management practices to prevent these outcomes.

Research Needs:

Increased agricultural intensification will require research to understand and predict how sediment transport and deposition is affected by water, wind, and climate variables. Measurement techniques, including remote sensing tools, are needed to monitor and address erosion rates through space and time. The need continues to evaluate newly emerging soil and water management strategies to understand how they affect soil properties, salinity, and remediation. This knowledge and understanding will facilitate the development, calibration, and validation of expert systems and modeling software essential to improved management and remediation strategies for soils that have been adversely impacted by erosion, compaction, and salinity. Assessing the impact of management practices on soil properties and processes requires multi-year studies, so, it is imperative to coordinate and leverage ongoing studies with existing ARS long-term research efforts to better understand how a changing climate affects soil erosion dynamics.

Anticipated Products

- Management practices that reduce and mitigate the effects of soil degradation and restore soil function;
- Improved multi-scale models and sensors to predict impacts of management effects on soil degradation; and
- Technologies for minimizing cropping system tillage to increase resilience to climate change and reduce erosion.

Potential Benefits

- Resilient, sustainable soil that meets societal production needs and provides essential ecosystem services.

Problem Statement 1B: ***Agricultural management for resilient soil***.

Agriculture must be intensified to meet expanding societal needs for food, feed, fiber, and fuel, while incorporating management practices that mitigate greenhouse gas emissions. Practices must also sequester atmospheric carbon, improve nutrient use efficiency, and promote soil health for resilient soil. Agricultural management affects mass and energy fluxes between soil and air that are directly related to physical, chemical, and biological properties promoting soil health and crop productivity. Agriculture plays a pivotal role as both a source and sink for greenhouse gases, which provides producers an opportunity to reduce and mitigate greenhouse gas emissions. Cost-effective agricultural practices for resilient soil will vary, depending on cropping systems, soil types, and climatic conditions. Modifying soil systems to meet complex and sometimes competing societal needs is even more challenging because of the need to consider how climate change will affect soil systems. Emerging enzymatic, thermochemical, and hydrochemical bioenergy platforms present new agricultural opportunities, but research is needed to ensure feedstock harvest and production practices promote good soil health and related agroecosystem services.

Research Needs

Multidisciplinary team efforts are essential for developing and improving whole-farm process models for life cycle analyses. Research is needed in developing and evaluating soil management practices, including the use of cover crops and soil amendments, to mitigate greenhouse gas emissions, sequester carbon, promote nutrient cycling, and build and promote healthy resilient soils for a range of soil types, cropping systems, and climates.

New tools, such as a comprehensive soil health index that integrates new information about the effects of management on soil physical, chemical and biological properties, are needed to reliably assess how extensively sustainable cropping practices have been adopted across agricultural landscapes. In addition, spatial, temporal, and mechanistic soil studies are needed to elucidate underlying mechanisms contributing to changes in soil carbon sequestration, soil health, greenhouse gas emission, and biogeochemical cycles. Furthermore, there is a need to identify how soil health contributes to climate change adaptation and/or is affected by climate change. Work is also needed to identify mitigation strategies that increase carbon sequestration while maintaining higher yields. This would include long-term holistic data on systems performance (soil properties, nutrient cycling, microbial communities, yield, and profitability) across agricultural landscapes. This would also include expanding national databases such as GRACEnet and REAP to facilitate the continuing process of refining, validating, and calibrating predictive and process models. New and improved methods, measurement techniques, and remote sensing technology are needed to facilitate sampling and mapping soil properties for use in facilitating rapid, accurate, and cost-effective sampling and mapping of landscape properties and fluxes. Research is needed on thermochemical coproducts, which can be used as soil amendments, to identify properties in these materials that enhance or degrade soil quality.

Anticipated Products

- New and improved sensors and measurement tools;
- Improved or new multi-scale predictive and process models and decision support tools;
- Predictions of carbon stock changes in diverse agroecosystems using process-based models and climate data;
- Management practices that promote soil quality, enhance soil health and increase carbon sequestration, mitigate greenhouse gas emissions, and/or increase soil resilience to climate change (e.g., drought);
- Expanded and new databases providing information relevant to the mission of the USDA Climate Change Hub network, GRACEnet, and LTAR databases; and
- Soil Health Index (indicator).

Potential Benefits

- Sustainable agricultural systems;
- Increased soil resilience to climate change (e.g., drought);
- Enhanced soil quality and soil health;
- Increased soil carbon sequestration; and
- Reduced greenhouse gas emissions.

Problem Statement 1C: ***Enhancing soil biodiversity and functions***

As agricultural intensification proceeds, a greater understanding of soil biodiversity could prevent degradation and enhance soil sustainability and resilience. Recent advancements in soil biology studies will improve scientific assessments of how different management strategies affect sustainability and soil degradation.

Soil health improvement will also require more research on soil microbial functions. This work is critical for increasing the basic and applied understanding of soil organisms and communities and can contribute to the development of new soil health indices and microbiological databases for beneficial soil microorganisms. There is a need to cooperate with other scientists working on different communities of the soil ecosystem (e.g., bacteria, archaea, fungi, viruses, nematodes, insects, and roots) as well as scientific cooperation on phytobiome studies. More information is needed about how crops affect or are affected by microbial communities and how these relationships can be managed to improve soil health and productivity.

Understanding the soil ecosystem can enhance our understanding of soil-plant interactions, long-term changes in soil health, and agricultural production sustainability. Research on soil ecosystems will require applications of new techniques such as high-throughput sequencing, computational biology, and many "omics" technologies to enable exploration of soil community composition, function, and activity.

Research Needs:

Soil health is widely recognized as the basis for robust and sustainable agricultural production systems that are necessary for food security, but even basic information about soil health and associated processes/functions is woefully inadequate. Many of the soil processes that influence, and are influenced by, agricultural productivity are not understood. Consequently, insufficient information is available to optimize soil biological processes to promote nutrient availability, provide pest and pathogen protection, and ensure sustainable production. Incorporating factors associated with changing environmental conditions and climates makes this effort even more difficult. Improved measurements of soil health will be crucial to ascertain the effects and interactions of cropping, management practices (conventional and conservation tillage, organic practices), and amendments (e.g., biofuels, biochar, compost, nanomaterials) on agricultural intensification and sustainability. Furthermore, there is a need to identify how species or communities (soil biology) contribute to climate change adaptation and/or are affected by climate change. Such measurements, to be most effective, should be applicable across cropping systems and geographic regions.

Anticipated Products

- Functional models based on increased understanding of the soil biome and agricultural practices;
- Science-based strategies and agricultural practices that can improve the biological component of soil health and ecosystem services;
- Management practices that can improve the soil biology component of soil health resilience to climate change;

- A new national soil microbiome/soil ecosystem database that includes new soil microbiome species, communities, and functions; and
- New and/or improved methodologies for the assessment of microbial community structure and function, particularly as it relates to soil health.

Potential Benefits

- Improved agricultural production and ecosystem services supported by improved understanding of soil biology processes; and
- Resilient and healthy soils that are needed for sustainable agricultural systems as a result of improved soil biology properties and functions.

COMPONENT 1 RESOURCES

Twenty-one (21) ARS research projects that are coded to National Program 212 address the research problems identified under Component 1. ARS locations that are assigned to these projects include:

AMES	IA	
AUBURN	AL	
BELTSVILLE	MD	(3 projects)
BOWLING GREEN	KY	
BROOKINGS	SD	
BUSHLAND	TX	
CLAY CENTER	NE	
FAYETTEVILLE	AR	
FLORENCE	SC	(2 projects)
FORT COLLINS	CO	
LUBBOCK	TX	
MANDAN	ND	
MORRIS	MN	
PENDLETON	OR	
PULLMAN	WA	
ST. PAUL	MN	
TIFTON	GA	
WYNDMOOR	PA	

COMPONENT 2: MANAGING NUTRIENTS IN AGROECOSYSTEMS

Best nutrient management practices can ensure optimal soil nutrient levels for meeting the requirements of crops and forages. Such management practices are critical to maintain good economic returns, higher sustainable yields, low environmental impacts, and sustainability of ecosystem services. Optimizing nitrogen and phosphorous inputs through efficient management practices is crucial for increasing economic returns for land managers and reducing agricultural pollutants in watersheds. Achieving this optimization requires more information about nutrient inputs and cycling from manures, composts, agricultural byproducts, cover crops, and other nutrient sources. Data from long- term nutrient management studies that incorporate crop varieties for a wide range of soil types and environments is essential.

Problem Statement 2A***: Improving Nitrogen Management.***
Nitrogen is a very important nutrient, but it is also highly mobile and can be found in air, soil, and water. Irrigation, precipitation events and snow melt can contribute to the off-site transport of nitrogen via surface transport, leaching or denitrification, and a changing climate may well exacerbate these losses. Ammonia volatilization is another pathway by which nitrogen is lost from cropping systems, and nitrogen can also accumulate in ecosystems via atmospheric dry and wet deposition.

Nitrogen management and conservation practices can help reduce nitrogen losses, but efforts are still needed to increase nitrogen use efficiency and reduce the loss of reactive nitrogen from agricultural systems. ARS has multidisciplinary scientific teams with expertise in soils, ecological engineering, hydrology, livestock management and nutrition, horticulture, and other areas working to improve nitrogen management, increase nitrogen use efficiencies, and reduce reactive nitrogen losses. More work is needed to increase collaborations between these different research fields on improving nitrogen management and reducing the movement of nitrogen from the soil phase to the air phase. Work is also needed on increasing nitrogen cycling, and, when possible, using nitrification inhibitors and other biogeochemical strategies to increase nitrogen use efficiencies. Reducing reactive nitrogen losses and improving nitrogen management is a challenge that will require collaborations between ARS, universities, and extension, as well as with farmers, producers, industry, and other partners.

Research Needs:
Research is needed to improve agricultural production and environmental control systems and best management practices that increase fertilizer and manure nitrogen use efficiencies.

The effects of amending soil with animal manures and agricultural bioproducts, needs further study, especially on how these amendments support crop growth and affect nitrogen cycling. Findings could help reduce crop production costs by replacing a portion of mineral fertilizer with manure nutrients. This will also require an increased knowledge of soil microbial processes and how those processes respond to nitrogen management. Work is also needed to identify management practices that reduce nitrous oxide and nitrogen emissions (e.g. ammonia) during fertilizer and manure applications; mitigation strategies that increase nitrogen use efficiency while maintaining higher yields; and new information about the nitrogen cycle at the field level. Research is also needed toward the long-term expansion of GRACEnet and other databases to provide ecosystem services that can help in estimating greenhouse emissions for use in future water and air trading markets.

Anticipated Products
- Guidelines and best management practices for efficient use of fertilizer, animal manure, composts, byproducts, and other organic bioresources to minimize nitrogen loses;

- A new regional/national best nitrogen management practices database that includes nitrogen management practices for cover crops, crop rotations, and management of manure and other byproduct inputs;
- Decision support tools (e.g., models, apps, nitrogen indices) and databases for improved nitrogen management to be use by action agencies, policymakers, farmers, extension, and other cooperators;
- Improved models using calibration and validation approaches that exploit extensive data sets such as the GRACEnet/REAP data management system for providing estimates of national reactive nitrogen gas losses; and
- Nutrient control monitoring systems that reduce nitrogen losses to the environment.

Potential Benefits

- Increased sustainable yields and profits for farmers and the protection of human health and ecosystems;
- Safer water and reduced losses of nitrogen from land application areas;
- Improved understanding and assessment of soil nitrogen cycle processes and nitrogen loss pathways;
- Less environmental risk through improved understanding of how spatial and temporal variability affects reactive nitrogen losses; and
- Increased productivity, profitability, and environmental stewardship through improved manure and fertilizer management and increased nitrogen use efficiency.

Problem Statement 2B: ***Improving phosphorus management***.

Manure is a valuable source of phosphorus and can be used as fertilizer to reduce crop production costs. Increased phosphorus application efficiencies are needed to enhance and ensure sustainable agricultural production and to reduce environmental degradation of water sources. Phosphorus studies will result in a better understanding of the biological and physical cycles of soil phosphorus, as well as more information about phosphorus supplies from fertilizer, crop residues, cover crops, manure, and byproducts. This information will support efforts to improve cost-effective phosphorus management in crop production. Reducing phosphorous losses and improving phosphorus management is a challenge that will require collaborations between ARS, universities, and extension, as well as with farmers, producers, industry, and other partners.

Research Needs

Too much available phosphorus can result in negative environmental impacts. Research is needed on strategies to reduce phosphorus losses from surface runoff and leaching. Work is also needed to assess the effects of legacy phosphorus in the soil, including the impact on mycorrhizal fungi and other components of soil biological communities. Legacy phosphorus in the soil may require decades of management to reach environmentally acceptable levels. Practices are needed to mitigate its effects, including the use of soil amendments, and to manage the release of bioavailable manure-phosphorus to crops. Research is also needed on the roles of rhizosphere microbiology and enzymology in phosphorus turnover controls. There is limited understanding of the persistence of impacts of past phosphorus loadings and management, which is reducing the development of remedial BMP options. Research is needed for more accurate phosphorus management tools (models and Phosphorus-Index), and on using cover crops, chemical/physical agents, or other management strategies to increase plant-available phosphorus in soil through biological cycling. This can also include supporting the efficient use of phosphorus from byproducts via optimizing phosphorus release from manure/agricultural byproducts.

Anticipated Products

- Guidelines and best management practices for efficient use of animal manure, composts, byproducts, and other organic bioresources to optimize the phosphorus release;
- Guidelines to reduce phosphorus occurrence in aquatic environments;
- Expanded technologies to support increased phosphorus use efficiency;
- Improved model routines for describing phosphorus fate and transport in soils; and
- Improved field-scale models or decision support systems, such as the Phosphorus Index, to improve environmental management of soil phosphorous.

Potential Benefits

- Enhanced, sustainable yields;
- Increased efficiency and reduced production costs through exploitation of on-site bioproducts, such as manure;
- Increased economic return and reduced environmental risk through improved phosphorus use and recovery from animal production systems;
- Reduced phosphorus in aquatic environments; and
- Improved water quality and reduced eutrophication.

Problem Statement 2C*: Improved Understanding of Macro- and Micro-nutrient Cycling in Soils.*

A better understanding of soil biological communities and ecosystems, including plant roots and root exudates, is essential for better nutrient management. Nitrogen and phosphorus applications significantly increase yields and the uptake of other macro and micronutrients. New technologies and a better understanding of soil chemistry may allow for significant improvement in macro and micro-nutrient management. Nutrient cycling from agricultural amendments such as manure, fertilizers, and other agricultural byproducts are primary methods for providing necessary macro and micro nutrients to crops, and cover crops can be used to recycle nutrients to subsequent crops. Fertilizer costs and associated energy costs, can vary considerably, and using cover crops (green manures), on-site manure, and other agricultural bioproducts can reduce costs and ensure nutrient availability.

Research Needs

Studies are needed on the removal rates of macro- and micro-nutrients from new, higher-yield cropping systems and from removing crop residues for bioenergy production. Long-term studies are needed to assess macro and micro-nutrients cycling in these cropping systems, as well as how cover crops and byproducts used to amend soils affect the potential cycling of macro- and micro-nutrients. Databases and decision support systems are needed to help farmers make science-based decisions that can contribute to increased yields, economic returns, and soil and water conservation.

Anticipated Products

- New and improved technologies for efficient collection, storage, use, and treatment of manure macro and micro-nutrients;
- Soil microbial inoculants for improving macro and micro-nutrient crop uptake;
- Value-added agricultural, industrial, and municipal byproducts with new macro and micro-nutrients' beneficial uses;
- New proximal nutrient sensors;
- Guidelines for efficient use of byproducts, with macro and micro-nutrient recommendations;
- Improved technologies to recycle and recover nutrients; and
- A new national/regional macro & micro-nutrient database that includes new best nutrient management practices for cover crops, crop rotations, and management of manure and other byproduct inputs, that can be used to construct models simulating crop management strategies and their effect on crop yields and macro and micro-nutrient cycling in soils.

Potential Benefits

- Increased yields;
- Increased farmer profits;
- Enhanced, sustainable agricultural systems;
- Improved macro and micro-nutrient use efficiency;
- Improved soil and water quality;
- Improved science foundation for water quality credit programs;
- Efficient use of byproducts; and
- Improved collection, storage, and treatment of manure nutrients.

COMPONENT 2 RESOURCES

Twenty (20) ARS research projects that are coded to National Program 212 address the research problems identified under Component 2. ARS locations that are assigned to these projects include:

AMES	IA	(2 projects)
AUBURN	AL	
BELTSVILLE	MD	(3 projects)
BOWLING GREEN	KY	
BROOKINGS	SD	
BUSHLAND	TX	
CLAY CENTER	NE	
FAYETTEVILLE	AR	
FLORENCE	SC	
FORT COLLINS	CO	
KIMBERLY	ID	

LINCOLN	NE
MADISON	WI
MORRIS	MN
PULLMAN	WA
ST. PAUL	MN
TIFTON	GA

COMPONENT 3. REDUCING ENVIRONMENTAL RISK OF AGRICULTURAL OPERATIONS

The loss of potential contaminants from agricultural landscapes to the surrounding environment can pose potential risks to plant, animal, and human health. These contaminants include pathogens, antibiotic-resistant bacteria, antibiotic-resistance genes, particulates of less than 10µm (PM_{10}), gases, odorants, volatile organic compounds (VOCs), agrochemicals, pharmaceutically active compounds (PACs), heavy metals, and other contaminants. The generation, transport, and loss of these constituents and other materials of concern may be exacerbated by changing weather patterns attributed to climate change. A critical need exists to conduct research that will help reduce these potentially hazardous contaminants in agricultural systems.

Some agricultural, municipal, and industrial byproducts have potential for helping to restore soil and water quality and reduce undesirable air emissions, but assessments are needed to determine if this use might result in possible risks to human health. ARS can contribute research that supports cost-benefit assessments of using byproducts for remediation activities, as well as for identifying how these byproducts might be used in plant and animal production systems to improve soil and water quality and soil and plant health.

Research opportunities exist for understanding the source and processes that control the generation and transport of these emissions/materials from agricultural systems; creating and/or enhancing methods for monitoring and predicting contaminant losses from agricultural landscapes; and developing cost-effective management practices, tools, and systems to ameliorate these losses and their negative impacts on human and ecosystem health.

Robust prediction methods via modeling and other techniques would be helpful for assessing and managing offsite agricultural losses. Long-term studies of management practices can be utilized to reduce pathogens and antibiotic resistance, reduce emissions from livestock systems, reduce environmental risk of potential contaminants from cropping and post-harvest systems, and reduce risk and increase beneficial uses of agricultural, industrial, and municipal byproducts.

Problem Statement 3A: ***Reducing pathogens and antibiotic resistance*****.**

In agricultural systems, native soil-borne microbes are enriched by contributions from manures, composts, plant wastes, and other byproducts. Soil-borne and manure-borne pathogens cause economically important diseases. Soil is a natural reservoir of antibiotic-resistant bacteria and antibiotic resistance genes, and there is concern that agricultural use of antibiotics and the land application of manures can enrich drug resistance among soil bacteria. Research is needed to survey and measure extant genetic antimicrobial resistance in soil to determine the specific impacts of agricultural management practices and whether resistance genes can be transferred into bacteria that cause disease. Agricultural antibiotics are thought to be transported off-site via the movement of manure-impacted soils in runoff, water, and air, and there is little information on how long antibiotics, other pharmaceuticals, resistant bacteria, and their genes persist in the environment or how they might affect soil functions.

Research Needs

Work is needed to develop management systems and conservation practices that control and contain soil-borne and manure-borne microbes. To reduce off-site transport, information is needed at a range of landscape scales on the fate and transport of microbes and pharmaceutical chemicals. This includes information on how these substances are affected by management practices, tillage, soil type, and fluctuating climate conditions, and how they might be remediated via interactions with soil constituents, biochars, and other agricultural byproducts. It is essential to develop methods for measuring resistant bacteria and resistance genes in complex agricultural samples; describe relationships between the pharmaceutical chemicals, bacteria, and genes; incorporate baseline and control measurements; identify environmental "hot spots" of resistance; and collect data on how resistance changes over time at different locations.

Anticipated Products

- Manure, soil, and waste treatment practices that mitigate pathogens and antibiotic resistance in agricultural, livestock, industrial, and municipal waste streams;
- Agricultural best management practices that reduce the off-site transport of pathogens and antibiotic resistance, including improved fate and transport models, survival data, and persistence data;
- Validated methods and procedures for measuring pathogens and antibiotic resistance in agroecosystems, and data measuring these parameters through time and space; and
- New database containing information about the types and amounts of antibiotic resistance on farms and in the environment.

Potential Benefits

- Improved plant, animal, human, and environmental health; and
- Fewer pathogens, antibiotic-resistant bacteria, and antibiotic resistance genes being transported within and outside of agroecosystems.

Problem Statement 3B: ***Managing Emissions from Farm Animal Systems.***

Livestock production systems will need to adapt to meet new national, State and regional emission standards and regulations. The development of a database related to emissions and management practices to reduce emissions is desperately needed to support the development of effective regulatory and policymaking tools by action agencies. In addition, information is needed on the reactivity of emissions originating from livestock operations, and how the transport of these constituents ultimately affects air quality on a regional or national scale. Tools to predict emissions from livestock production systems will be needed to better understand, manage, and control emissions and protect agricultural workers, animals, neighboring communities, and natural areas. These prediction capabilities will assist in the development of baseline values to evaluate new emission reduction practices.

Technologies are also needed to minimize emissions and capture valuable nutrients, and reduce odors associated with livestock housing, manure handling/storage, and land application of manures. It is critical that the storage, handling, and land application of manure and agricultural byproducts be improved, as well as development of realistic and cost-effective waste management practices for a variety of livestock systems.

Research Needs

Characterization is needed of the major emissions pathways of gases and particulates/aerosols from livestock production systems, including information on emissions processes, temporal and spatial variability, and effects of climate and management practices on emissions. This includes the transport, deposition, and reactivity of emitted compounds and their effects on air and environmental quality. An important need is the evaluation and improvement of greenhouse gas inventories, models, and decision support tools that predict emissions from livestock whole-farm systems and describe chemical transformations within the manure, soil, and air, and fate of reactive compounds. Work is also needed to help other agencies scale up farm-scale emissions data to scales that meet their requirements, as well as to fill information gaps on how these processes will be impacted by changing climate and long-term management at a given location.

There is a need for development and evaluation of cost-effective emissions mitigation practices applicable at different phases of livestock production, including animal diets and feeding strategies, improved animal management and manure handling/treatment systems, and improved land application methods for manures. Novel techniques for odor adsorption and dispersion, as well as nutrient capture and re-use, would be helpful to farmers and ranchers.

Anticipated Products

- Livestock emission database that can be used for developing emission factors for whole farm systems and for model testing and validation;
- Technical guidelines for measuring/monitoring emissions from livestock production systems;
- Guidelines and on farm technologies to mitigate emissions from livestock operations, and assessments of mitigation strategy effectiveness;
- Improved mathematical, process-based simulation models and decision support tools that include dietary and management factors for predicting whole-farm gaseous and particulate/aerosol emissions, as well as transport and reactivity of these constituents in the atmosphere;
- Improved treatment technologies to capture nutrients and reduce emissions from livestock production systems; and
- Improved estimates for the USDA Agriculture Greenhouse Gas Inventory, EPA

National Emissions Inventory, and Intergovernmental Panel on Climate Change.

Potential Benefits

- Livestock producers are able to meet air emissions standards due to more accurate emission factors, inventories, models, and decision support tools that take into account livestock systems, climate, and management practices;
- Improved livestock system management that meets the growing demand for food, reduces the environmental footprint of production, and improves production and economic returns for farmers and ranchers; and
- Expanded use and contributions to Livestock GRACEnet (database, technical guidelines, and technology transfer) and information relevant to the mission of the USDA Climate Change Hub network.

Problem Statement 3C: *Reducing Environmental Risk of Potential Contaminants from Cropping and Post-Harvest Systems.*

Data concerning the losses, transport, and fate of potential contaminants are lacking for many cropping systems at scales ranging from complex micro-environments to landscapes and regions, making management and policy decisions difficult. The effects of climate change on these processes are poorly understood. Datasets for post-harvest systems, such as cotton ginning and nut-hull removal, are incomplete. Volatile and semi-volatile agrochemicals and their formulations used in row crops can affect environmental quality. Heavy metals, pharmaceutically active compounds, and other emerging contaminants of concern are potential carcinogens, endocrine disruptors, or can be detrimental to animal, plant, and human health. Particulate matter may be transported offsite through erosion of fine dust particles due to wind erosion or through volatilization via energy/radiation and meteorological forcing. Emissions from land application of manure can affect neighboring communities and impact environmental quality at local and regional levels. Studies are needed that reflect realistic and economically viable management practices. Characterization and quantification will provide the necessary data to develop predictive models and enable the development of management practices to reduce these losses.

Research Needs

Research is needed to characterize the major pathways and factors affecting release, transport, and fate of particulate matter, volatile inorganic compounds, agrochemicals, soil particles, and greenhouse gas from agricultural production systems. Research is needed to characterize and quantify how bioactive compounds affect soils, plants, water quality, nutrient cycling, and organic matter decomposition, including how compounds of concerns are metabolized and transferred to edible plant tissues. More information is needed about how soil microbial communities and their activities affect the mission and fate of volatile compounds, nitrogenous compounds, methane, and hydrogen sulfide.

More research on particulate emissions from cropping and post-harvest agricultural operations is needed since newly promulgated air quality standards for particulate matter less than 2.5 microns ($PM_{2.5}$) have affected State Implementation Plans and triggered changes in the permitting process for agricultural operations. Research is required to develop additional drift mitigation technology and models for agrochemicals, as well as information concerning practices designed to minimize drift during application and control post-application volatilization and re-deposition.

The interactions of potential contaminants across different landscapes and management combinations and the effects of a changing climate on contaminant releases need to be characterized and quantified. Information is needed to identify best management practices that reduce chemical losses and remediate trace element problems, and sediment losses, as well as computer models that can assess emissions and facilitate the evaluation of different management scenarios.

Anticipated Products

- Improved methods to detect the environmental concentrations of potential contaminants in agroecosystems and quantify their release, transport, and fate;
- Databases for modeling losses of potential contaminants from agricultural systems under varying climatic conditions that can be used in discerning factors affecting release, transport, and fate and for simulation studies;
- New or improved mathematical and process-based simulation models for predicting release, transport, and fate of potential contaminants to guide management practices;
- Practical best management guidelines for the use, remediation, and control of agrochemicals that are tailored to the individual needs of diverse agricultural production systems; and
- New phytoremediation tools designed to help urban and traditional farmers speed the removal of soil contaminants so that the contaminants are not taken up by crops.

Potential Benefits

- Improved sustainable production systems that help meet the growing national and global demand for food;
- Producers are able to meet State and Federal air quality regulations through better understanding of factors influencing contaminant transport and fate that consider crop type, climate, and management practices; and
- Reduced environmental risk of potential contaminants transport from agricultural operations, which will help protect air, water, and soil, and lower the risk of food-safety related problems in crop production.

Problem Statement 3D: *Reducing Risk and Developing Beneficial Agricultural Uses of Agricultural, Industrial, and Municipal Byproducts*.

Many agricultural, municipal, and industrial byproducts, if properly processed and used, may have specific benefits to water quality, soil quality, air quality, plant health, and plant and animal production systems. These byproducts need to be used in an environmentally sound manner that reduces disposal costs or converts them into marketable assets. The Environmental Protection Agency is actively encouraging Industrial Materials Recycling, with regulations adopted at the State level. At this time, State regulatory agencies lack tools for evaluating the beneficial use of these byproducts in agriculture or horticulture for their environmental sustainability. Research could provide critical information to State regulatory agencies about constituent phyto- and bio-availability in byproduct amendments, and guidance on how to use these data to conduct pathway risk assessments to support use decisions. Municipal waste streams contain unused plant nutrients such as nitrogen and phosphorus, and technologies are being tested for their recapture, which would reduce the loss of essential plant nutrients by recycling them and minimize nutrient pollution of water bodies.

Research Needs

Technologically sound methods are needed for processing byproducts into beneficial products that are commercially sustainable. This includes blending, composting, and amending byproducts, as well as developing land application and management techniques that will improve soil, water, and air quality and support plant growth. Many regulators are reluctant to approve land application, soil manufacturing, and other agricultural and horticultural uses of byproducts because they don't have information about how these byproducts may interact with soils, nutrient bioavailability, groundwater, and other soil-related functions and processes. Developing methods to examine and approve byproducts based on sound science will protect environmental quality; improve soil, water, and air quality; and increase profits for byproduct generators and the agricultural community. Research is also needed on improved formulations of agriculture byproducts as feedstock for industrial and agricultural applications. This includes creating and testing prototype byproducts for existing processes and technologies, measuring the fate and transport of byproduct components, measuring treatment efficacy and controlling processes, identifying beneficial properties, developing innovative processes, and applying real time cost-benefit evaluations to the findings. Research on the potential of these byproducts to improve soil physical and chemical properties and reclaim degraded soils is also needed.

Anticipated Products

- Byproducts that improve soils and/or remediate degraded or contaminated soils;
- Byproducts for use as components of manufactured soils, such as potting material in the horticulture industry;
- New agricultural byproducts for industrial applications;
- Guidelines for using byproducts to stabilize or sequester nutrients in manures and soils;
- Guidelines for beneficial uses of agriculture, industrial, and municipal byproducts;
- Byproduct-use decision trees for State, City, or Local agencies;
- Procedures to evaluate, process, and apply byproducts for long-term benefit; Generic test models or analyses;
- A model process for evaluating different types of byproducts for agricultural and horticultural use;
- Innovative products and processes to make agricultural economics more efficient and that add quality and value and/or lower feedstock costs for industrial processes; and
- Established sampling, analysis, and assessment protocols for agriculture, industrial, and municipal byproducts that provide accurate and reliable data for risk assessments.

Potential Benefits

- Improved environmental quality;
- Economic benefits from the use of byproducts; and
- Expanded and safer use of byproducts from and for agriculture.

COMPONENT 3 RESOURCES

Twenty-three (23) ARS research projects that are coded to National Program 212 address the research problems identified under Component 3. ARS locations that are assigned to these projects include:

AMES	IA	(2 projects)
AUBURN	AL	
BELTSVILLE	MD	(3 projects)
BOWLING GREEN	KY	
BUSHLAND	TX	
CLAY CENTER	NE	
FAYETTEVILLE	AR	
FLORENCE	SC	
KIMBERLY	ID	
LINCOLN	NE	
LUBBOCK	TX	
MADISON	WI	
PEORIA	IL	
PULLMAN	WA	
RIVERSIDE	CA	(2 projects)
ST. PAUL	MN	
TIFTON	GA	
UNIVERSITY PARK	PA	
WYNDMOOR	PA	