FY2017 Annual Report
National Program 212 –Soil and Air

Introduction

National Program (NP) 212, Soil and Air, conducts research that seeks: to improve the quality of atmosphere and soil resources that both affect and are affected by agriculture; to understand the effects of climate change on agriculture; and to prepare agriculture for adaptation to climate change. Its overarching research goals therefore examine science-based approaches that (1) expand, maintain, enhance, and protect soil resources essential for U.S. agricultural production; (2) optimize the management of crop nutrients and greenhouse gas emissions (GHG) from agricultural soils and byproducts, and (3) explore options for agricultural production management in the face of global climate change.

Agricultural systems function within the soil-atmosphere continuum. Mass and energy exchange processes occur both across and throughout this continuum and agriculture can significantly affect the processes and the magnitude of fluxes between the soil and atmosphere. As one component of the continuum, soils are a crucial resource for agriculture: they must be managed to meet rising global demands for food, feed, fiber, fuel and ecosystem services - while maintaining soil productivity and limiting undesirable interactions between soils and the atmosphere.
Likewise, the atmosphere is also a critical component in agriculture: uptake of Nitrogen by soil microbes increases soil fertility, yet, emissions from agriculture to the atmosphere may affect air quality and increase atmospheric greenhouse gas (GHG) concentrations. While GHG emissions from soils are a natural part of the critical natural carbon (C) and nitrogen (N) cycles, altered emissions can also contribute to climate change. Furthermore, as a result, a changing climate can impact agricultural production - ranging from small- to large-scale farms; to small pasture to large rangeland cattle operations (and others). These impacts arise through alterations in precipitation and temperature patterns and through increased atmospheric carbon dioxide (CO_2) concentrations. The impacts of climate change create challenges that need to be met in managing agricultural operations to reduce GHG emissions while concurrently maintaining or enhancing the productivity of their underlying soil resources. These changes also present new opportunities for agricultural production research and strategy development and for investigation of new approaches to enhance soil quality and to holistically mange the soil-air continuum.

The variability of the atmosphere, soils, and plants, and the complexity of interactions among these systems require collaborations by ARS scientists conducting NP212 research. Formal and informal Cross Location Research (CLR) projects including the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), Resilient Economic Agricultural Production (REAP), and field campaigns focused on air quality and remote sensing of soil moisture are successful examples.

Synthesis and integration of information, including sources outside NP212, by CLR projects increases the utility and impact of ARS research. Efficient assimilation of data from NP212 projects into existing and future collaborative data bases will enhance synthesis and integration analyses and expand research opportunities.

During FY 2017, 82 full-time scientists working at 19 locations across the U.S. were actively engaged in 24 ARS-led and 103 cooperative research projects in NP212. ARS-lead projects were approved through the ARS Office of Scientific Quality Review in 2017, making this the first year of implementation of these projects. The fiscal year 2017 funding for NP212 was $45 million.

Personnel News for NP212

New scientists in NP212 in 2017:

- Microbiologist **Dr. Getahun Agga** joined the Food Animal Environmental Systems Research Unit, Bowling Green KY, after completing a postdoctoral research position with ARS in Nebraska. Dr. Agga studies antimicrobial resistance and other food safety issues.
- The Integrated Cropping Systems Research Laboratory in Brookings SD hosted **Dr. Steven Rosenzweig**, a visiting soil scientist from General Mills, in 2017. Dr. Rosenzweig is working on developing sustainable cropping systems for cereals in the Great Plains.
- The Soil, Water & Air Resources Research Laboratory, Ames IA, had a visiting Fulbright Scholar in 2017: **Dr. Hamada Abdelrahman** is an Assistant Professor from Cairo University, Egypt. His area of expertise is soil organic matter--its composition and cycling in agroecosystems.
- The Coastal Plains Soil, Water and Plant Research Center, Florence SC had several visiting scientists in 2017: **Dr. Virginia H. Takata**, from the Soil and Water Department, University of the Republic, Uruguay, collaborated with ARS Florence Center on research for recovering phosphorus from dairy wastes using the Quick Wash method developed by ARS Florence scientists. **Dr. Marina De Pra**, from EMBRAPA, Brazil, conducted research on deammonification with anammox and helped develop procedures for microscopic fluorescence images of *Brocadia caroliniensis* in consociation with nitrifiers using a state-of-the-art confocal microscope. The images supported a CRADA with Pancopia Inc. that allowed industry to advance quickly in their media selection for space bioreactors. **Drs. Heechul Choi and Sang-Ryong Lee**, from the National Institute of Animal Science - Korean Rural Development Agency (RDA), participated in Florence’s swine odor reduction experiments using various biochar materials. Their research was funded by a RDA-ARS International Cooperative Research Agreement to develop a swine odor removal system using biochar.

- The Hydrology and Remote Sensing Laboratory, Beltsville MD, hosted two visiting scientists in 2017: **Professor Jie Cheng** is from the School of Geography, Beijing Normal University, and is conducting research on estimating evapotranspiration (ET) with thermal-based energy balance models developed by HRSL researchers over heterogeneous land surfaces in China and the U.S. **Dr. Fangni Lei** is from Wuhan University (Wuhan, China). She is currently working on the assimilation of high-resolution, thermal-based remote sensing information into a soil water balance model for improved irrigation management within vineyards. This work is contributing to the USDA-NASA funded GRAPEX project. HRSL also gained a new postdoctoral research associate in 2017: **Dr. Tiffany Wilson** is working on integrating a water balance model specifically developed for vineyards with the remote sensing-based evapotranspiration modeling system developed by HRSL scientists for monitoring vineyard root zone soil moisture and vine stress for improved irrigation scheduling.
- **Dr. Dan Schlatter**, formerly of the University of Minnesota, joined the Northwest Sustainable Agroecosystem Research Unit, Pullman WA, as a postdoctoral research associate. Dr. Schlatter is working on DNA sequencing of microbes in windblown dust and cropping systems.
- **Dr. Josh Gamble** joined the Soil & Water Management Unit, St. Paul MN, as a postdoctoral research associate. Dr. Gamble received his PhD from the University of Minnesota, and has been part of the Dairy Agroecosytem Working Group (DAWG) project.

The following scientists retired from the ranks in NP212:

- **Dr. Rufus Chaney,** Senior Research Agronomist, retired after 47 years with ARS at the Beltsville Agriculture Research Center. Dr. Chaney is a member of the ARS Hall of Fame and is an international expert in assessing the health and environmental risks posed by heavy metals in contaminated soils, in biosolids, and in food crops. Dr. Chaney is a recipient of numerous awards, most recently being the Presidential Rank Meritorious Senior Professional Award and the International Phytotechnology Society's Gordon Award for career achievement in phyto-remediation.
- Soil Scientist **Dr. Gary Lehrsch** retired from the Northwest Irrigation & Soils Research Laboratory, Kimberly, ID.
- Soil microbiologist **Dr. Ann Kennedy** retired from the Northwest Sustainable Agroecosystem Research Unit, Pullman WA.

The distinguished record of service of these scientists is recognized world-wide, and they will be missed in NP212.

The following scientists in NP 212 received prominent awards in 2017:

- **Drs. H. Allen Torbert and Dexter Watts** of the National Soil Dynamics Laboratory, Auburn AL, were both named "Pioneer of Agricultural Gypsum" by the American Coal Ash Association, in recognition of their research efforts for the use of gypsum in agriculture, including the "Beneficial Use" of FGD gypsum in agriculture.
- **Drs. Matias Vanotti, Ariel Szogi,** and **Michael Rothrock** were awarded the 2017 *Excellence in Technology Transfer Project of the Year Award* by the South East Region of the Federal Laboratory Consortium for Technology Transfer (FLC). The award was given to the team for their work with Pancopia, Inc. (Bill Cumbie, CEO), and NASA – in the effort "Novel Anammox Bacterium Isolate for Purification and Recycling Wastewater in Space and Decentralized Wastewater Systems"
- **Dr. Lisa Durso** of the Agroecosystem Management Research Unit, Lincoln NE, received an "Outstanding Associate Editor" award from the Journal of Environmental Quality.
- Also in the Agroecosystem Management Research Unit, **Dr. John E. Gilley** received a 2017 American Society of Agricultural and Biological Engineers Superior Paper Award for the manuscript: "*Removal of cattle manure constituents in runoff from no-till cropland as affected by setback distance*." Dr. Gilley was also selected as an Outstanding Associate Editor for the American Society of Agricultural and Biological Engineers Journals.
- The Environmentally Integrated Dairy Management Research Unit, Marshfield WI, celebrated two awards in 2017: **Drs. Mark Borchardt and Tucker Burch** received an Educational Blue Ribbon Award from Transactions of the ASABE for their work on "Considerations for the Use of Manure Irrigation Practices," and **Dr. Wayne Coblentz** received the Agronomy Journal *Editor's Citation for Excellence* as a Reviewer for his work in 2016.
- **Drs. Matias B. Vanotti and Ariel A. Szogi** of the Coastal Plains Soil, Water and Plant Research Center, Florence SC, received the Federal Laboratory Consortium – Southeast Region Award: 2017 Excellence in Technology Transfer Project of the Year entitled "Novel Anammox Bacterium Isolate for Purification and Recycling Wastewater in Space and Decentralized Wastewater Systems."
- **Dr. Jorge Delgado** of the Soil Management and Sugar Beet Research Unit, Ft. Collins CO, received the American Society of Agronomy Environmental Quality Research Award. This award is intended to recognize contributions that have enhanced the basic understanding of environmental sciences in relation to agriculture, or demonstrated sound and effective management practices for maintaining or improving the quality of soil, water, and air resources.
- **Dr. Hero Gollany** of the Soil and Water Conservation Research Unit, Pendleton OR, was named a 2017 fellow of the Soil Science Society of America.

The quality and impact of NP 212 research was further evidenced in 2017 by the following:

- 160 refereed journal articles published
- one new patent application, one new patent issued and four new invention disclosures submitted
- 2 new cooperative research and development agreements and six new material transfer agreements with stakeholders

In 2017, NP 212 scientists participated in research collaborations with scientists in Australia, Belgium, Brazil, Cambodia, Canada, China, Congo (Democratic), Egypt, Ethiopia, Germany, Ireland, Italy, Mexico, Netherlands, New Zealand, Northern Ireland, Philippines, South Korea, Spain, Sweden, United Kingdom, and Uruguay.

Significant Accomplishments for FY2017

This section summarizes significant and high impact research results that address specific components of the FY 2016-2020 action plan for NP 212. Each section summarizes accomplishments of individual research projects in NP 212. Many of the programs summarized for FY 2017 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA - ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs.

Management and stewardship of soil resources

The first component of the Soil and Air National Program focuses on research and development of approaches that promote agricultural soil fertility and sustainability – to promote "healthy" soils that enable good stewardship of our nation's soils. While hard to quantitatively define "healthy" soils, they are considered ones that sustained and even improve in both their productivity and resilience to disease; they are managed in such a way as to maintain these characteristics enabling them to be sustainable. Healthy soils are key to agricultural productivity. In addition to being productive, resistant to disease, and sustainable, healthy soils also have features that enable them to resist external fluctuations that would negatively affect a less "healthy" soil. One important set of such external fluctuations are extreme climatic events (e.g., droughts, intensive precipitation, and higher and lower temperatures) – that are increasing in frequency and intensity, and that adversely affect both agricultural productivity and soil resources. Soil erosion by wind and water is a problem to current and future production - despite agricultural management efforts to protect soil. In some settings, some tillage and the lack of cover cropping or cover residue also contribute to off-site transport of soil particles. Finally, soil compaction, soil acidification, and buildup of salts also contribute to soil degradation. By conducting research that examines and establishes approaches for soils to be productive, resistant to disease, sustainable and more resilient to climate change –Soil and Air scientists are improving the ability of our agricultural soils to perform even under a wide range of disturbances.

Selected Accomplishments

The greenhouse gas reduction through agricultural carbon enhancement network (GRACEnet) project. There is a need to improve the functionality of GRACEnet by addressing wide scale agricultural management impacts on soil carbon and greenhouse gas (GHG) emissions. The GRACEnet community has continued to develop and expand the power of GRACEnet by establishing new field/laboratory measurement protocols, refining a standardized Excel data entry template, developing and implementing software to perform quality control of data entry, and a introducing a web-accessible

GRACEnet database. The public portal of the data management system was further improved during FY 2017 and integrated with the Natural Resource and Genomics Data Systems server. The GRACEnet web portal now contains extensive data from 17 ARS Locations with more than 450,000 total records including 116,000 soil GHG (greenhouse gas) emission measurements and 83,000 soil measurements. Furthermore, the data developed by the GRACEnet network and housed by the GRACEnet project have been used to increase the accuracy of GHG emission estimates reported in the U.S. national GHG inventories, including the latest EPA (Environmental Protection Agency) inventory published in FY 2017. Additionally, project data have been used to develop scaling factors to quantify the GHG reductions for improved management practices. GRACEnet data are now being used to validate the underlying models used by the Natural Resources Conservation Service (NRCS) Carbon Online Management Evaluation Tool (COMET-Farm) decision support tool.

Wheat yields and soil water improve under no-tillage practices. Farmers in the inland Pacific Northwest have doubted whether knowledge gained from small plot experiments can be transferred to farm fields, and whether no-tillage provides sufficient soil water for autumn planting of winter wheat. ARS researchers at Pendleton, Oregon, compared soil water content and winter wheat yields between traditional inversion tillage and current no-tillage technology in two upland drainages in the 12- to 14-inch rainfall region. They found winter wheat yields to be similar between no-tillage and conventional tillage, and there was significantly more plant available water in topsoil before planting under no-tillage than traditional tillage. These results confirmed that improvements in herbicides, equipment, and wheat varieties in the last 30 years have resolved earlier plant-water problems in no-tillage practices and demonstrate that the soil-conserving practice of no-tillage is capable of meeting or exceeding crop productivity from traditional inversion tillage. This work will increase adoption and development of no-tillage cropping systems in the inland Pacific Northwest.

Use of fungus inoculum increased yield in eggplants. The Grand Challenge of ARS is to increase crop yields with reduced input of resources. One option is the intentional use of naturally-occurring symbioses between soil microorganisms and plant roots such as the one formed by arbuscular mycorrhizal [AM] fungi. ARS researchers at Wyndmoor, Pennsylvania conducted two years of experimentation at conventional vegetable farms which showed increases in yield of eggplant fruit of 6-18% by weight. Fungus inocula were produced on-farm at a cost of less than a penny per plant. This result demonstrates the great potential for the use of AM fungi to increase the yield of vegetables without increased inputs.

Management practice to increase deep soil organic carbon. Intensive tillage, low biomass inputs, fallow, and straw burning in the past decades have greatly decreased soil organic carbon in the Pacific Northwest dryland production region. Crop productivity and soil health requires that soil organic carbon is maintained or increased. ARS researchers in Pendleton, Oregon, used producers' fields to measure soil carbon to

60 inch depth during the early 1980s and again in the early 2000s. Winter wheat with peas increased deep soil organic carbon the most, followed by the conservation reserve program and winter wheat with reduced tillage. These results will encourage the development and adoption of deep-rooted legumes, such as peas in the rotation, reducing tillage and reducing fallow for sustainable wheat production.

Evaluation of molecular assay for a rapid detection of Salmonella in beef cattle. Food animal production environment presents a complex challenge for the persistence of foodborne pathogens such as Salmonella. Cattle are asymptomatic carriers of Salmonella continuously shedding bacteria into the environment resulting in hide contamination which can subsequently lead to carcass contamination posing a significant food safety risk. In collaboration with ARS scientists in Clay Center, Nebraska, scientists from a commercial manufacturer, and an ARS scientist in Bowling Green, Kentucky conducted a study to evaluate an automated detection assay for the detection and quantification of Salmonella from rectoanal mucosal swabs (RAMS) collected from beef cattle. When tested on enriched RAMS samples, this method was 100% sensitive and specific for the detection of Salmonella. When used on RAMS samples without enrichment it showed 67% sensitivity and 100% specificity compared to a culture method. This method provided a rapid and reliable procedure for the detection and quantification of Salmonella from RAMS in feedlot cattle, reducing time to result by 3 days, reducing labor and supply cost, with the potential for improvement of the safety of beef supply, through early detection.

Reduced nitrogen loss, increased soil carbon and crop yields by crop diversification. Improving crop production practices will increase producer profit and minimize any negative off-farm impacts. Diversification of crop rotations is a fundamental tactic that can produce substantial producer and societal benefits. Using long-term research plots established in the northern Corn Belt, ARS researchers at Brookings, South Dakota evaluated a two-year conventional corn-soybean rotation in comparison to a four-year corn-field peas-winter wheat-corn rotation. Both cropping rotations were conducted under no-till conditions. Compared to the two-year rotation, the four-year rotation increased soybean yield by 22%, decreased by 24% the loss of nitrogen through atmospheric emissions of nitrous oxide, and increased the rate and depth of soil organic carbon accumulation. Results demonstrate that crop production systems can be adjusted to achieve higher yields and retain more nutrients and carbon in soil compared to existing practices. It is critical to have demonstrated solutions that apply to regionally-specific conditions and management practices so that producers can respond to market and policy influences. Improving the efficiency of cropping systems improves producer profitability, reduces soil loss and degradation, and supports public interests by improving water and air quality.

myPhyloDB — a cutting-edge tool to aid the standardization, normalization, and technology transfer of metagenomics data. The advent of next-generation sequencing has led to a dramatic increase in analysis of genetic material for microbial populations from a variety of sources (e.g., soil, human, animal). However, current analysis platforms do not allow for the convenient storage or standardization necessary for efficient technology transfer and cross-study analyses. An ARS researcher in Fort Collins, Colorado developed myPhyloDB to fill the need for a database that includes soil biology and soil biology responses to management. This new web-based tool is a significant accomplishment that provides an easy-to-use graphical interface and adds new functionality to the DNA sequence processing capabilities of Mothur – the most widely cited bioinformatics program (4000+ citations). The first version of myPhyloDB has been downloaded or distributed via CD-ROM to more than 100 different research groups, from fields ranging from soil microbial ecology to human health and nutrition to help them resolve scientific problems. The web-based site has had 1,616 visitors from at least 73 countries.

DayCent model testing and application. A unique accomplishment of this study was to use the model to simulate changes in soil carbon under different management practices using field data from long term (more than 80 years) conventional till wheat/fallow plots in Oregon. The model was capable of representing the observed large losses of soil carbon for plots that received no fertilizer or where residue was burned, moderate carbon losses in plots that were amended with synthetic fertilizer or pea vine residue, and carbon gains for plots fertilized with cattle manure. The model also correctly represented the observed higher yields of plots that received fertilizer compared to plots that were not fertilized. The model then was used to predict future changes in soil carbon up to the year 2080. Model results suggest the plots that were losing carbon would continue to do so under conventional tillage, but the rate of loss should decrease as soil carbon levels approach a new equilibrium. For the manure plots that were gaining carbon, the model predicts that additional carbon gains would be minimal and a new equilibrium would be reached in about the year 2020. In contrast, if the plots were converted to no till, the model predicts small to moderate C gains, depending on residue management, for plots that were amended with fertilizer, pea vine, or manure, and minimal gains for the zero-fertilizer treatment. The model will be a valuable tool to recommend management practices that increase carbon sequestration in this region of the USA.

Managing nutrients in agroecosystems

The second component of the Soil and Air National Program Action Plan focuses on research and development to enable agricultural producers to optimize nutrient use in their agroecosystems. The development of such best nutrient management practices will lead ensure that producers can use optimal soil nutrient levels to meet the requirements of crops and forages. These management practices furthermore enable good economic returns, higher sustainable yields, lower environmental impacts, and increase the sustainability of their operation's ecosystem services. Optimizing nitrogen and phosphorous inputs through efficient management practices is a critical component to balance increasing economic returns for land managers while at the same time, 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. The efforts of the Soil and Air scientists focusing on these efforts will enable agricultural producers to optimize their use of nutrients, save money, and lower losses of expensive fertilizers to the environment.

Selected Accomplishments

Nitrogen captured from a farming operations ammonia scrubber was as good as or better than commercial nitrogen fertilizer. One of the biggest environmental problems associated with the poultry industry is ammonia emissions from poultry houses, which cause air and water pollution. Scientists at Fayetteville, Arkansas, have developed the ARS Air Scrubber, which captures ammonia and dust emitted from poultry houses. This year we found that when tall fescue plots were fertilized with scrubber solutions containing nitrogen captured from poultry house emissions using alum, potassium bisulfate, sodium bisulfate, or sulfuric acid, the yields were equal to or greater than ammonium nitrate fertilizer applications at the same rate of nitrogen (100 pounds per acre). The potential impact of this research is enormous, since in Arkansas alone over 100 million pounds of ammonia are emitted each year from poultry houses which could be captured and used as fertilizer.

A patented method of using microbial inoculants to reduce nitrous oxide (N_2O) emissions associated with nitrogen (N) fertilizer application. ARS researchers at Auburn, Alabama, have identified microbial inoculants that can improve plant production and improve plant nutrient efficiency. Of particular interest is the development of a microbial inoculants that will also reduce N_2O losses form fertilizer nitrogen use. The loss of N_2O is of particular concern not only because of the loss of N so that plants cannot use it, but also due to its potential to contribute to global warming. Over the past few decades, N_2O emissions have increased worldwide due to several factors, including increases in cultivated crop area, excessive applications of N fertilizers, and livestock production. But losses of N_2O from fertilizer is considered to be the largest contributor to global warming from agriculture as a whole. Ongoing research led to the discovery that specific soil microorganisms applied with the correct fertilizer can reduce N_2O emissions, which was the bases of the patent. As a result, new management tools were developed to reduce N_2O emissions from production agriculture.

Greenhouse gas emissions from manure more accurately and quickly measured. Nitrous oxide is a greenhouse gas emitted from cattle manure and soils. Nitrous oxide emissions have traditionally been measured using chambers that cover the emitting surface and rely on several gas samples collected over a 30 to 60 minute period. However such methods provide poor time resolution, thus, ARS scientists from Bushland, Texas, and Texas A&M AgriLife Research, Amarillo, Texas, developed an improved method that relies on a real-time, continuous nitrous oxide analyzer to accurately quantify nitrous oxide emissions from manure and soil in only 60 seconds. The improved method resulted in faster and more accurate measurement of greenhouse gas emissions from manure that revealed new dynamics in nitrous oxide emissions.

Tile drainage and delayed fertilizer application reduce nitrous oxide fluxes. Nitrous oxide has increased in concentration in the atmosphere by more than 20% since 1750, due largely to the application of fertilizers and manures. To date, no studies have evaluated nitrous oxide emissions under different combinations of fertilizer application timing and soil drainage conditions for corn. In this study, ARS scientists in St. Paul, Minnesota collaborated with University of Minnesota faculty on a two-year field experiment that compared nitrous oxide emissions following single, pre-plant fertilizer application versus a double, split fertilizer application with and without tile drainage. The split application also used microbial inhibitors designed to reduce microbial transformations of applied nitrogen. Averaged across years, the undrained soil emitted 1.8 times more nitrous oxide than the tile drained soil, and the double, split application emitted 26% less nitrous oxide than the single, pre-plant application with no grain yield differences. These results provide scientists and land managers with potential strategies for reducing losses of nitrous oxide emissions from fertilized soils.

Crop diversity: a recipe for productive and sustainable agriculture. Highly specialized cash-grain production systems based upon corn-soybean rotations under tilled soil management are common in the northwestern U.S. Corn Belt. This rotation is expensive to maintain in terms of agricultural inputs needed such as pesticides and fertilizer cost. A long-term study, initiated in 1997 by ARS researchers at Brookings, South Dakota, was conducted to determine if diversification of this ubiquitous corn-soybean rotation would affect soil characteristics and crop productivity under no-till soil management. They determined the effects of a 2-year rotation (corn-soybean), 3-year rotation (corn-soybean-spring wheat), and 5-year rotation (corn-soybean-oat/pea hay-alfalfa-alfalfa) on soil bulk density, soil carbon sequestration, and residual soil nitrate-N as well as on corn and soybean yield productivity and seed protein. They found that diversification of the corn-soybean rotation with oat/pea and alfalfa hay made soils less dense, increased soil carbon, increased soil nitrogen available to corn and soybean phases, and increased corn and soybean grain yield as well as seed protein. In contrast, diversification with wheat only increased corn and soybean grain yield. Findings were communicated to producers, crop consultants and scientist through various outreach activities. These data elucidate the complex relationships between soil attributes, crop rotations, and crop yield that help provide a basis for improving the productivity and sustainability of agricultural systems to meet the demand for increased productivity while maintaining or improving the soil resource.

Reducing environmental risk of agricultural operations

The third component of the Soil and Air National Program Action Plan focuses on research that evaluates approaches to lower environmental risks that may arise from agriculture. One of the most commonly thought of risks that agriculture is thought to pose arises from chemicals that are used in agriculture (e.g., fertilizers or pesticides) that migrate off-site and have undesirable consequences to surrounding environments. The potential loss of such contaminants from agricultural landscapes to the surrounding environment can pose potential risks to plant, animal, and human health. These contaminants include agrochemicals; gases; odorants; volatile organic compounds (VOCs) and other airborne contaminants (e.g., particulates of less than 10μm [PM10]); pharmaceutically active compounds (PACs); and even pathogens, antibiotic-resistant bacteria, antibiotic-resistance genes, heavy metals, and other contaminants. Not only is off-site transport of high concern, but the generation, transport, and loss of these constituents and other materials of concern may be exacerbated by changing weather patterns attributed to climate change. Therefore, there is a critical need to conduct research that will help reduce these potentially hazardous contaminants in agricultural systems – which is the focus of this component of research.

Selected Accomplishments

Recovery of ammonia and production of high-grade phosphates from animal and municipal effluents. New processes and technologies to recover and re-use nutrients from wastes are desirable to close the nutrient cycle in modern human society and address future scarcity of non-renewable nutrients and fossil-based fertilizers. Therefore, conservation and recovery of nitrogen (N) and phosphorus (P) from wastes are important because of economic and environmental reasons. ARS researchers at Florence, South Carolina, have developed a new technology that allows separation and recovery of both ammonia and phosphorus from liquid effluents. A U.S. patent application was filed in 2016 (USDA Docket 83.15). The new technology uses gas-permeable membranes at low pressure that are submerged in the manure liquid. The technology can recover 98% of the N. The process was further improved with little aeration that reduced costs by 70%. The low-rate aeration replaced alkali chemicals that were needed to raise the pH for optimum nitrogen recovery. An additional breakthrough came when the N process was combined with P recovery. Since ammonia and carbonates were taken out, the combined process produced phosphorus bio-minerals containing a very-high phosphate grade (46%), similar to commercial fertilizer favored by the fertilizer industry. The process provided 100% P recovery efficiencies. This technology has applications for anaerobic digester effluents in swine operations, dairies and municipalities. The potential value of recovered P and N from implementation of nutrient recovery technology in dairy farms is about 1.3 billion dollars. The invention provides a more competitive technology for nutrient recovery from the side-stream effluent of municipal plants that contains high P and N concentration. Users are entrepreneurs, livestock producers, municipalities, industrialists, extension practitioners and other scientists interested in manure nutrient recovery technologies.

No-tillage reduces particulate emissions in the Inland Pacific Northwest. Wind erosion from the traditional tillage-based winter wheat–summer fallow dryland cropping system adversely affects air quality in the Inland Pacific Northwest United States. No-tillage systems have the potential to reduce the risk of wind erosion. ARS scientists from Pullman, Washington, measured wind erosion from tillage-based winter wheat-summer fallow and no-tillage spring cereal cropping systems near Ralston, Washington. Although not yet economically viable, no-tillage systems reduced wind erosion and particulate emissions by as much as ninety percent in this environmentally sensitive agricultural region.

Quantification of Escherichia coli O157 in environmental samples. An improved approach for quantifying low concentrations of the pathogen E. coli O157 in environmental samples was evaluated by an ARS scientist in Riverside, California. The specificity and detection limit of E. coli O157 in inoculated samples of fresh produce, soil, and water was determined. The assay was further applied to swine, dairy, beef, and poultry manure, and wastewater effluent collected from a dairy wetland over a twelve-month period. The assay quantified E. coli O157 with concentrations below 100 cells per gram of soil or manure. The accuracy of this assay will enable the quantification of low cell numbers of E. coli O157 in environmental samples, providing a valuable tool to growers and researchers to protect humans from E. coli O157 contamination.

Lower ammonia and odor emissions through diet formulation. Livestock production is the main source of ammonia (NH_3) in the environment and limiting nitrogen into the system will reduce the emissions of NH_3. Lowering the crude protein (CP) content of animal diets has the potential to lower NH_3 emissions. A swine feeding trial in Ames, Iowa was conducted to test this hypothesis with amino acid supplements replacing CP levels. Data from this study showed that NH_3 and odor emissions were both reduced by 9.6% and 5% for each percent reduction of CP in the diet. The source of protein in the diet also impacted emissions of both ammonia and odor. Animal diet reformulations with crystalline amino acids have the potential to lower emissions thereby reducing the environmental footprint of swine facilities.

Biochar increases soil organic carbon but not always crop yield. Biochar can remediate degraded soils and maintain or improve soil health, but predictable effects on soil properties and crop productivity are unknown. A collaboration between Iowa State University and ARS researchers at six different locations across the U.S. showed that a fast-pyrolysis, hardwood biochar increased soil organic carbon content by 48% in the top six inches of soil across a broad range of temperate soils. However, crop yield responses to biochar should only be expected when specific soil quality problems limit productivity such as limited water or nutrient retention capacity. This research suggests that biochars could be a more effective soil amendment if they were produced to have specific chemical and physical properties to address specific soil problems in addition to storing atmospheric carbon in agricultural soils.

Optimizing manure anaerobic digestion for pathogen control. Anaerobic digestion of manure is used on dairy farms to produce energy. The process also can destroy zoonotic pathogens that infect both livestock and humans. Digestion is often paired with manure separation on large dairy farms where separated solids are used as cattle bedding. The extent of pathogen destruction in digesters is not well-characterized, and the distribution of pathogens in solid and liquid fractions of separated manure is not known. ARS researchers in Marshfield, Wisconsin studied seven manure digesters with separators and determined that pathogen destruction is suboptimal and highly variable among farms and seasons. Surviving pathogens ultimately end up in the liquid fraction of separated manure, which can result in human exposure during land-application. This research shows livestock producers that they must optimize the performance of their digesters to maximize public health benefits. Fortunately, optimization also is likely to improve biogas yields during digestion, which in turn improves the economic viability of digesters.

Response of a southeastern pasture system to elevated CO_2 evaluated. Although much is known about plant responses to rising atmospheric CO_2 levels, how pasture systems in the southeastern U.S. will respond to predicted future atmospheric CO_2 concentrations remains unstudied. Researchers at the National Soil Dynamics Laboratory, Auburn, Alabama, determined above- and belowground biomass in a bahiagrass pasture exposed to ambient or elevated CO_2 and either managed (with nitrogen (N) addition) or unmanaged (no N addition) for 10 years. Soil water, carbon and nitrogen have also been determined in this study. To date, results show that plant biomass only shows a positive response to elevated CO_2 when nitrogen is added. Data from this study will add to the understanding of plant responses to rising atmospheric CO_2 which will be useful for modelers and policy-makers. Results will also be of use to producers and may indicate a need to shift from unmanaged to managed systems to take advantage of the rising level of atmospheric CO_2 for increased productivity and profitability.

Improved methane emission estimates from dairy lagoons in the Western U.S. Methane generation from dairy liquid storage systems is a major source of agricultural greenhouse gas emissions; however, there has been little on-farm research conducted to estimate these emissions. ARS researchers in Kimberly, Idaho, measured methane emissions on six dairy farms and determined that emissions from dairy lagoons varied seasonally and were heavily dependent on the volatile solids, total nitrogen, and pH in the lagoon in addition to air temperature and wind speed. Annual methane emissions measured on these farms were twice as much as those estimated using the current Environmental Protection Agency methodologies. An alternative estimation methodology that used a volatile solids degradation factor provided better estimates of methane emissions from dairy lagoons. The improved methodology will provide more accurate estimates of methane contribution from dairy lagoons, which will provide more reasonable estimates for reduction targets.