FY2019 Annual Report
National Program 212 Soil and Air

Introduction

The Soil and Air National Program (NP212) conducts research that seeks to improve the quality of atmospheric 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 research focuses on 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.

Background: Agricultural systems function within the complex soil-atmosphere (and water) continuum. Mass and energy exchange processes occur both across and throughout this continuum - and agricultural operations have substantial effects on the processes and on the magnitude of fluxes between the soil and atmosphere – wherever agricultural systems are in place.

As one component of the continuum, agricultural soils are a crucial and dynamic resource: they must be managed to meet rising global demands for food, feed, fiber, fuel and ecosystem services and - via strategic, science-based management - they must be managed to enhance soil productivity and limit undesirable interactions between soils and the atmosphere.

Likewise, the atmosphere is also a crucial and dynamic component in agriculture. For example, uptake of atmospheric nitrogen (N) by soil microbes increases soil fertility, yet, nitrogenous emissions [e.g., nitrous oxide (N_2O) and ammonia (NH_3)] from soil ecosystems to the atmosphere may affect air quality and increase atmospheric greenhouse gas (GHG) concentrations. Similar trends between atmospheric and soil carbon (C) fluxes exist: C fixation from atmospheric CO_2 to carbohydrates is performed by leguminous plants and photosynthetic microorganisms found in soils. Other microbes (and plants) also release C to the atmosphere in the form of CO_2 and CH_4 (primarily). While the GHG emissions from any soil are considered a natural part of the critical C and N cycles, altered emissions found in agricultural operations can also change flux dynamics that contribute to climate change.

Furthermore, a changing climate can impact agricultural production at all scales - ranging from small- to large-scale cropping and orchard operations and from small pasture to large rangeland cattle operations (and others). These impacts are not limited to GHG changes but can arise through alterations in precipitation and temperature patterns. Climate change impacts 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, strategy development, and investigation of new approaches to enhance soil quality and 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), a number of CLR soil microbiome research efforts, 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.

Activities and Impact: During FY 2019, NP212 had 81 full-time scientists working at 19 locations across the U.S. who were actively engaged in 23 ARS-appropriated projects and 92 cooperative research projects. NP212 base funding for FY19 was $39.4M.

Personnel News for NP212

New scientists in NP212 in 2019:

- **Dr. Peter Vadas** of ARS's Dairy Forage Research Center, Marshfield WI, has joined the ARS Office of National Programs as the new NPL for Land and Air. Dr. Vadas will be overseeing parts of NP 212 as well as NP215 (Grass, Forage, and Rangeland Agroecosystems).
- **Dr. Wade Heller** joined the Molecular Characterization of Foodborne Pathogens Research Unit in Wyndmoor PA in June of 2019. Dr. Heller recently completed a postdoctoral research position at the University of Hawaii where he had been working on an ARS-funded research project. Dr. Heller is resuming research on "Production, Utilization, and Importance of Arbuscular Mycorrhizal Fungi in Sustainable Vegetable Production," which had been dormant since the retirement of Dr. David Douds in 2017.
- Two new scientists joined the Northwest Irrigation & Soils Research Lab in Kimberly, ID. **Dr. Chris Rogers** was formerly an Assistant Professor and Barley Agronomist with University of Idaho. Chris currently conducts research in carbon and nutrient uptake by crops. He will be involved with crop production studies that include dairy manure application and more aspirational crop rotations. **Dr. Kossi Nouwakpo** was formerly a Research Assistant Professor with University of Nevada, Reno, working closely with ARS's Great Basin Rangeland Research Unit in Reno. Kossi will be involved with a

variety of water quality studies, especially CEAP, to determine effects of irrigation, tillage and crop effects on water balances and sediment and nutrient losses.

- The Soil and Water Conservation Research Unit in Pendleton OR welcomed two visiting scientists in 2019: **Dr. Kofi K. Boateng** from Ghana and Dr. **Adnan Zahid** from Pakistan. They were funded through Climate Food and Farming - Global Research Alliance Development Scholarships (CLIFF-GRADs) to get training on the soil carbon model CQESTR and greenhouse gas emissions measurements.
- The Agroecosystem Management Research Unit in Lincoln NE welcomed postdoctoral research associate **Li Lidong**. Dr. Li received her Ph.D. in Environmental and Soil Science from the University of Tennessee – Knoxville. She is working on analysis of data associated with the REAP program.
- **Dr. Abimbola Ojekanmi** joined the Soil Management Research Laboratory in Morris MN as an ORISE post-doc in June 2019. He is a recent graduate of the University of Alberta, Canada. Through a grant from the National Corn Growers Association, Dr. Ojekanmi is conducting synthesis of corn stover data to establish scientifically based guidelines of what mass of corn stover may be harvested without impacting soil organic carbon stocks and, conversely, the potential increase in SOC stocks that could be credited for retaining corn stover.
- **Dr. Melissa Motew** joined the Dairy Forage Research Center, Marshfield WI for 2019 as a postdoctoral research associate. Dr. Motew received her PhD from the University of Wisconsin-Madison and while at ARS performed simulation modeling of land surface processes, with focus areas in agriculture, climate change, freshwater, and ecosystem services.
- **Dr. Tulsi Kharel** recently joined the Poultry Production and Product Safety Research Unit in Fayetteville AR for a two-year postdoctoral research associate position. Tulsi came to Fayetteville from Cornell University, and over the next two years, he will work with big data in systems agriculture, handling spatially and temporally disparate data for making systems-level inferences.
- The Soil Dynamics Research Laboratory in Auburn AL welcomed **Dr. Aleksandr Kavetskiy** of Russia in 2019. Dr. Kavetskiy is a nuclear physicist with expertise in soil element analysis scanning.
- The Hydrology and Remote Sensing Laboratory in Beltsville MD welcomed the following visitors in 2019: **Theophilius Baah** is a visiting Mandela Fellow from Paynesville, Liberia. Mr. Baah is an agronomist and agriculture extension technician interested in the enhancement of productivity by smallholder farmers in low-input agricultural production systems. **Dr. Ling Du** is a visiting postdoctoral research associate from China. She is working on Deep Learning approaches using lidar and optical data for characterizing agricultural landscapes. **Elton Vicente Escobar Silva** is a visiting graduate scholar in Environmental Science from the Federal University of São Carlos in São Carlos, Brasil. Mr. Escobar works on his Masters of Science project entitled 'Development of a Vegetation Growth Model Adapted to Urban Areas'. His goal is to combine vegetation modeling and remote sensing to manage vegetation in São Carlos.

The following scientists retired from or left the ranks of NP212:

- **Dr. Kristan Reed** of the Dairy Forage Research Center in Marshfield WI, left her post-doctoral ARS position for a faculty position at Cornell University.
- **Dr. Ali Sadeghi** retired from the Hydrology and Remote Sensing Laboratory in Beltsville MD. Dr. Sadeghi's most recent contributions included guiding watershed modeling approaches using SWAT, APEX and AnnAGNPS with a focus on water quality issues associated with Chesapeake Bay health.
- **Dr. Jack Meisinger** and **Dr. Thanh Dao** both retired from the Adaptive Cropping Systems Laboratory in Beltsville MD in 2019.

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 2019:

- **Dr. Amanda Ashworth of** the Poultry Production and Product Safety Research Unit in Fayetteville AR received the American Society of Agronomy Environmental Quality Inspiring Young Scientist Award; the ARS Southeast Area Early Career Research Scientist of the Year Award; and the ARS Herbert L. Rothbart Outstanding Early Career Scientist of the Year in 2019.
- **Dr. Matias Vanotti** of the Coastal Plains Soil, Water, and Plant Research Center, Florence SC, was elected as a Fellow by the Soil Science Society of America in 2019. Dr. Vanotti also received the 2019 ARS Senior Scientist of The Year Award "For Outstanding Scientific and Technological Advances in Waste Management and Wastewater Treatment Systems," and along with CPSWPRC colleagues Dr. Ariel A. Szogi, and Dr. Thomas F. Ducey, the 2019 Southeast Region Project of the Year, Excellence in Technology Transfer Award from the Federal Laboratory Consortium for "Odors and Ammonia Capping of Swine Lagoons Using High Performance Nitrifiers. "
- **Dr. Bryan Woodbury** of the Nutrition and Environmental Management Research Unit in Clay Center, NE received the ARS Plains Area Technology Transfer Award.
- **Dr. Richard Todd** of the Livestock Nutrient Management Research Unit, Bushland, TX was presented with the USDA-REE Undersecretary's Award in Washington, DC. Dr. Todd was recognized as a member of the multi-institutional Great Plains Grazing team for "expanding scientific knowledge, strengthening research and extension partnerships, and enhancing producers' adaptive capacity to sustain grazing lands and beef production in the Southern Great Plains". The team's research was funded by a competitive grant from the USDA National Institute of Food and Agriculture.

- **Dr. Heidi Waldrip** and **Dr. David Parker** of the Livestock Nutrient Management Research Unit, Bushland, TX and **Dr. Mindy Spiehs** and **Dr. Bryan Woodbury** of the Nutrition and Environmental Management Research Unit, Clay Center, NE received a Superior Paper Award from the American Society of Agricultural and Biological Engineers in July 2019 for their peer-reviewed manuscript "How do temperature and rainfall affect nitrous oxide emissions from open-lot beef cattle feedyards pens?"
- **Dr. Feng Gao** of the Hydrology and Remote Sensing Laboratory in Beltsville MD received the 2018 Arthur S. Flemming Award for Applied Science and Engineering in recognition of the original research in the application of remote sensing for crop and vegetation monitoring.
- **Dr. Ray Hunt** of the Hydrology and Remote Sensing Laboratory in Beltsville MD was one of the Top Ten Reviewers 2018 for *Remote Sensing of Environment* (the leading journal for science and applications of remote sensing). This award recognizes the number, quality, and speed of peer-reviews for submitted manuscripts.
- **Dr. Bill Kustas** of the Hydrology and Remote Sensing Laboratory in Beltsville MD received the 2019 Hydrologic Sciences Award from the American Geophysical Union. This award recognizes outstanding contributions to the science of hydrology, with an emphasis on the most recent five years of research activity.
- **Dr. Glenn Moglen** of the Hydrology and Remote Sensing Laboratory in Beltsville, MD received the 2019 "Best Technical Note" award from the American Society of Civil Engineers' Journal of Hydrologic Engineering for his paper entitled, "Parsimonious mathematical characterization of channel shape and size."
- **Dr. Eton Codling** of the Adaptive Cropping Systems Laboratory in Beltsville MD was presented with the Living Legends Award for service to humanity in February 2019. He was honored for mentoring under-represented high school, undergraduate and graduate students at USDA-ARS and the Tri Societies (ASA, SSSA and CSSA).
- **Dr. Scott Bradford** of the U.S. Salinity Laboratory, Riverside CA was awarded the 2019 Don & Betty Kirkham Soil Physics Award, a prestigious award administered by the Soil Science Society of America which recognizes mid-career scientists who have made outstanding contributions in the areas of soil physics.

The quality and impact of NP 212 research was further evidenced in FY 2019 by the following:

- 163 peer reviewed journal articles published and four new books or book chapters;
- two new patent applications and one new patent granted
- 17 new incoming agreements with collaborators
- 159 students and postdocs training with ARS

In FY 2019, NP 212 scientists participated in research collaborations with scientists in Australia, Brazil, Cambodia, Canada, China, Denmark, El Salvador, Ethiopia, Finland, France, Germany, Guatemala, Honduras, Ireland, Israel, Italy, Mexico, New Zealand, Nicaragua, Poland, South Korea, Spain, Sweden, and United Kingdom.

Significant Accomplishments for FY2019

The following sections summarize significant and high impact research results that address the three specific components of the FY 2016-2020 action plan for NP212. Many of the programs summarized for FY2019 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs.

Component 1. Management and stewardship of soil resources

Research in this component focuses on development of management approaches that promote agricultural soil fertility and sustainability (i.e. "healthy" soils) and provide tools for good stewardship of our nation's soils. While "healthy" soils are difficult to quantitatively define, they are considered to be ones that are managed to maintain and even improve their crop productivity as well as their resilience to climatic disturbances (e.g., droughts, intense precipitation, temperatures extremes), diseases, and invasive pests that would negatively affect less "healthy" soils. These climatic disturbances are of emerging importance, because they are increasing in frequency and intensity, and adversely affect both agricultural productivity and soil resources. In addition, healthy soils can moderate problems associated with wind and water erosion and their impact on current and future production. The Soil and Air national program builds on the foundational discoveries and agricultural management efforts that have been developed to protect soil. For example, in some settings, tillage and the lack of cover crops or crop residues contribute to off-site transport of soil particles. Research conducted by NP212 scientists on tillage management and cover cropping has had fundamental impacts on reducing erosion. Finally, soil compaction, soil acidification, and buildup of salts also contribute to soil degradation, and NP212 scientists conduct research to address these by investigating the positive impacts of, for example, cover cropping and biochar amendments. By conducting research that examines and establishes approaches for soils to be productive, resistant to disease, and more resilient to climate change –Soil and Air scientists are improving the ability of our agricultural soils to perform under a wide range of present and future conditions.

Selected Accomplishments

Perennial living mulch systems increase sustainability of corn and soybean production. Perennial living mulches are a farming management option that provide the environmental benefits of cover crops, such as reductions in both erosion and chemical runoff, but without the need to replant each year. One plant that is commonly used as a perennial living mulch is kura clover, a long-lived legume that spreads by rhizomes, but the factors that affect its agronomic performance and nutrient management are not well defined. ARS scientists in St. Paul, Minnesota, have been developing the management systems needed to successfully integrate kura clover-based living mulch systems into corn and soy production. They have also developed a novel rotary zone tillage (RZT) system that, in contrast to conventional strip tillage, the RZT units create 30-cm rows, which more effectively eliminates early season kura clover and reduces corn competition for light, water, and nutrients. The scientists have also shown that due to kura's nitrogen fixation ability, first-year corn following 2 to 3 years of kura management for forage does not require nitrogen fertilizer to maximize yield and profitability, whereas second-year corn requires only a reduced application of nitrogen fertilizer. The net economic return from corn grain and stover in the kura-corn system averaged over two seasons was $138 per hectare more than conventional corn production. The combination of the RZT management of the kura living mulch cropping system provides a promising system for corn growers that can return significantly greater economic and ecological outcomes.

A cutting-edge tool that enables 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 convenient storage or the standardization necessary for efficient technology transfer and cross-study analyses. ARS scientists in Fort Collins, Colorado, developed myPhyloDB to fill the need for a database that includes soil biology and its responses to management. This new web-based tool is a significant advancement 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 (4,000+ citations). myPhyloDB has been adopted as the designated platform for the ARS Soil Biology Group and is being integrated into the USDA Agricultural Collaborative Research Outcomes System (AgCROS) network. myPhyloDB has been downloaded or distributed via CD-ROM to more than 200 different international research groups in fields ranging from soil microbial ecology to human health and nutrition.

Cover crops can reduce impacts of crop residue removal. Harvesting crop residues for value-added uses can bring economic benefits for producers but removing residue from the soil can have a negative impact on soil health. Because removing residue decreases soil carbon and reduces ecosystem services in the long term, producers are adopting alternative management practices to protect their soil. Including cover crops can keep the soil protected from wind and water erosion, and improve soil chemical, biological and physical properties. Because of these advantages, cover crop acreage increased by 88.5 percent in South Dakota and by 79.1 percent throughout the United States between 2012 and 2017, as reported in the 2017 Census of Agriculture. Cover crops can easily be incorporated into production systems when cash crop residue is removed. ARS researchers in Brookings, South Dakota, and collaborators have shown a negative impact on soil health when crop residue is removed, but these impacts can be reduced by incorporating cover crops into the production system. Specific benefits included improved soil water infiltration and storage through improved soil aggregation, decreased greenhouse gas flux, improved microbial activity, and increased crop yield for the soybean phase when grown in a corn/soybean rotation. Action and education agencies such as the Natural Resources Conservation Service and university extension services can use these research results to illustrate to producers the benefits of adopting cover crops and identifying the best opportunities to use them in their cropping systems.

Farming practices impact gene abundance of soil bacteria responsible for nitrous oxide emissions, but relationships of potential nitrous oxide generation and actual emissions are unclear. Agricultural soils are a dominant source of nitrous oxide, a greenhouse gas and catalyst of stratospheric ozone decay. The dominant process in soils that leads to nitrous oxide production in many agricultural soils is denitrification, a process carried out by soil microbes. In a long-term study in Beltsville, Maryland, ARS scientists showed that the abundance of denitrification genes found in microorganisms was affected by the specific crop in a rotation, the time of year, and the farming system (no-till, conventional till, or organic). However, whereas these practices caused changes in the responsible gene quantities, the changes did not correspond to nitrous oxide emission patterns. This information is important in the on-going search for reliable indicators of microbially mediated soil greenhouse gas emissions and will be important for scientists to improve models predicting soil microbial community dynamics and greenhouse gas emissions.

Biostimulant additives applied with urea fertilizer result in unintended nitrogen losses. Urea is the dominant form of nitrogen fertilizer in much of the United States and globally. Various additives have been designed for co-application with urea to improve performance of nitrogen-intensive crops, including potato. Few studies have compared microbial “inhibitor” additives with so-called “biostimulants” designed to enhance plant growth or microbial activity. Over two growing seasons in an irrigated potato system, ARS scientists in St. Paul, Minnesota, found that a biostimulant containing nitrogen-fixing microbes (NFM) increased nitrous oxide (N2O) gas emissions by more than 30 percent, in contrast to the inhibitors, which decreased N2O emissions by more than 40 percent. Also, in the wetter of the two growing seasons, NFM also increased NO3− leaching by 23 percent. Biostimulants can have unintended impacts on reactive nitrogen losses and should be used with caution pending additional study to better understand their effects on biological processes and to quantify their performance in other agro-ecosystems. These results will assist producers and policymakers in developing practices for improving nutrient use efficiency and reducing nitrogen losses to the environment.

A new method for creating soil carbon content maps. Soil carbon mapping is extremely useful in assessing the effect of land management practices on soil carbon storage. ARS researchers in Auburn, Alabama, developed a method of using neutron-gamma analysis in scanning mode to map soil carbon (patent pending). A global positioning system device and software required to simultaneously acquire gamma signals and geographical positions during scanning operations were added to an existing measurement system. Soil carbon assessments by the inelastic neutron scattering (INS) method produced reliable soil carbon maps of agricultural fields using a mobile scanning mode. This method has also been demonstrated to provide reliable carbon analysis of soil cores using a stationary scanning mode. Findings indicated that the INS method can reliably and rapidly quantify carbon storage in agricultural soils. This critical rapid assessment can be used by scientists to identify best management practices that maintain soil productivity and help mitigate climate change.

Low-cost anaerobic digester for reduction of antibiotics and xenobiotics in farm waste. Waste management on farm for wastes ranging from animal manures to plant residues is an important issue because accumulated waste can be sources of pollution and potential human pathogens. ARS scientists in Beltsville, Maryland, in collaboration with scientists at the University of Maryland, College Park, tested an anaerobic digestion system that had been developed for small farms to reduce antibiotic compounds in farm waste. This anaerobic digestion system removed 70 percent of the antibiotic monensin, which is widely used in animal husbandry, from waste. Once implemented, anaerobic digestion systems such as this will have the potential to reduce point source pollution runoff from farms into the Chesapeake Bay and other important watersheds. This information will be important to policymakers and scientists developing methods to reduce on-farm waste.

Roles of organic matter in agricultural soils can be accurately studied through alkaline extraction for humic fractions. Pivotal roles of soil organic matter (SOM) in soil processes have long been studied by fractionating SOM into pure organic pools that are more amenable to chemical analyses. The classical fractionation approach, solubilization in alkaline solutions to extract humic fractions, has recently become increasingly criticized as being unfit for research because it allegedly produces new compounds that are not found in natural soils. In response to calls to ban publication of research involving alkaline extractions of SOM, the editor of the Journal of Environmental Quality (JEQ) invited ARS researchers in Ames, Iowa, to lead in publishing reviews that summarize practical applications of humic fractions for resolving multiple agricultural and environmental issues in soils and natural water bodies. The first review also provided evidence for only limited chemical alteration of SOM during alkaline extraction. Within 5 months of its publication, this review has been downloaded 3.5 times the average lifetime number of downloads for JEQ articles. A link to this review has been posted on the website of the International Humic Substances Society as a potential citation to support future manuscripts using alkaline extractions. The JEQ has since called for a special issue on alkaline extraction studies.

Biochar alters soil water retention, greenhouse gas emissions, nutrient cycling, and biology. Because atmosphere-derived carbon in biochar degrades slowly when mixed with soil, biochar can potentially help store carbon in soil. Collaborators at Iowa State

University and ARS researchers at six locations across the United States completed a project that examined the influence of biochar on soil physical and chemical properties in a broad range of soils. This work, which was reported in 12 publications including a final report completed in 2019, has had a substantial impact on society's understanding of biochar as a soil additive. To date, the project's research papers have been cited by more than 800 publications worldwide. This foundational research provides important guidance to researchers, farmers growing crops on biochar-amended soils, and land managers who wish to evaluate the economic benefits achieved by using biochar to store atmospheric carbon in agricultural soils.

Component 2. Managing nutrients in agroecosystems

This component focuses on research and development that allow agricultural producers to not only optimize nutrient use to meet the requirements of crops and forages for high yields and good economic returns, but also to lower environmental impacts and increase the sustainability of their operation's ecosystem services. For example, optimizing nitrogen and phosphorous inputs through efficient management practices requires more information about nutrient inputs and cycling from fertilizers, 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 are essential. The efforts of the Soil and Air scientists will enable agricultural producers to optimize their use of nutrients, save money, and lower losses of to the environment.

Selected Accomplishments

Innovative manure treatment addresses nutrient pollution problems and creates commercial products. Manure is often used as a farmland amendment to provide nitrogen, phosphorus, and organic matter for crops. Excess phosphorous found in some manures, however, can contaminate rivers, lakes, and bays through runoff. The recovery of phosphorus and proteins from manure prior to application to fields could be advantageous to offset treatment and storage costs, and to lessen the environmental impacts to land. ARS researchers in Florence, South Carolina, developed a new biorefinery process that recovers value-added phosphorus, proteins, and amino acids, and leftover solids from manures. An additional breakthrough came when sugars from sucrose, sugarbeet molasses, and peach waste were used as natural acid precursors to further lower treatment costs. These precursors allowed rapid fermentation, which produced abundant acids. These acids extracted nearly all the phosphorus and the acids also caused nearly all of the proteins to be concentrated in an easy-to-collect precipitate. The process is also effective at extracting phosphorus and proteins from other biological materials such as algae and soybean meal. The recovered proteins can be used to produce amino acids, and the recovered phosphorus can be used as a recycled material to replace commercial phosphate fertilizers. This innovation provides a means to create new revenue stream from farm wastes.

Near real-time mapping of crop phenology enables more accurate yield predictions. Crop progress information can benefit farmers in scheduling irrigation, fertilization, and harvest operations. Satellite remote sensing data are used to map crop phenology and growth stage. However, near real-time monitoring at the early stages of crop development during spring is still challenging due to the lack of cloud-free satellite observations. ARS scientists in Beltsville, Maryland, developed a new approach that combines historical Moderate Resolution Imaging Spectroradiometer (MODIS) data and the recently launched Visible Infrared Imaging Radiometer Suite (VIIRS). Results show that VIIRS imagery captures spatial variability of crop emergence resulting from different planting dates. Furthermore, estimated crop growth stage is correlated with phenology data reported by National Agricultural Statistics Service (NASS). The date that plants emerge from the soil is better than the planting date for predicting crop yield and will eventually increase the accuracy of NASS yield forecasts.

Reducing phosphorus problems by intensive investigation of best management practices. Although phosphorus runoff from pastures fertilized with animal manure can cause serious water quality problems, long-term studies on the effectiveness of grazing management practices in combination with other best management practices, such as rotational grazing, have never been carried out. Scientists from ARS in Fayetteville and Booneville, Arkansas, and University of Arkansas research partners conducted a long-term study to evaluate the effectiveness of grazing management and buffer strips on phosphorus runoff from pastures. The15-year study on 15 watersheds had five treatments: hayed, continuously grazed, rotationally grazed, rotationally grazed with an unfertilized buffer strip, and rotationally grazed with an unfertilized fenced riparian buffer. Rotational grazing alone did not reduce phosphorus loads in runoff compared to continuous grazing. However, phosphorus runoff was reduced by 36 percent with unfertilized buffer strips; 60 percent with fenced, unfertilized riparian buffers; and 49 percent by converting pastures to hayfields. The use of buffer strips and converted pastures to hayfields can be effective best management practices (BMPs) for reducing phosphorus runoff in southeastern U.S. pastures. The data can also be used to determine weighting factors for BMPs in phosphorus indices used for nutrient management planning.

Novel anammox bacterium isolate helps purify and recycle wastewater in the International Space Station (ISS) and decentralized wastewater systems. One of America's most widespread and costly environmental problems is nutrient pollution in streams and waterways caused by excess nitrogen and phosphorus in the environment. Using existing technologies to remove nitrogen from wastewater in treatment plants in the Chesapeake Bay alone costs an estimated $8.2 billion. These environmental problems can be mitigated with a biological process that uses novel approaches, such as the anammox bacteria to remove nitrogen from wastewater, because this can be done at one-third the cost of existing technologies. ARS researchers in Florence, South Carolina, developed an active anammox culture isolated from manure sludges, Brocadia caroliniensis, that thrives in high-ammonia environments and can reactivate after being held dormant. The process is stable, robust, and simple to use. This made the ARS anammox particularly attractive for use in wastewater treatment systems to help recycle the water used by astronauts in outer space, particularly those staying in the ISS. Water in outer space is a scarce commodity, costing $83,000 per gallon to transport it there. Recycling water in space is critical to minimizing operating costs and optimizing operations because water represents approximately 92 percent of total life-support consumables for the ISS. ARS has also teamed up with a commercial partner in Hampton, Virginia, to expand the use of the new technology to space exploration. The ARS discovered anammox was highly effective in NASA SBIR projects for 1) deammonification of high-ammonia early planetary space wastewater, and 2) its rapid reactivation after long periods of quiescent operations. The treatment systems using these organisms attained up to 95 percent removal of nitrogen from wastewater. The new technology could also be used in household septic tanks in the Chesapeake Bay watershed, where 52,000 septic systems need to be upgraded to be able to remove nitrogen.

Remote sensing for conservation tillage assessment can improve productivity and ecosystem service evaluations. Remote sensing indices are used to estimate soil tillage intensity based on the crop residue cover remaining in the field after planting. Soil moisture conditions affect the estimation of crop residue, and therefore, affect estimates of tillage intensity. However, the long revisit intervals of Landsat (i.e., 16 days), spring rains, and clouds have made it challenging to monitor soil tillage intensity. ARS scientists in Beltsville, Maryland, combined imagery from Landsat-8 and the European satellites Sentinel-2A and 2B to create a high-temporal-resolution dataset at 30-m spatial resolution for the 6- to 12-week period when most crops are planted. A new remote sensing algorithm to mitigate the uncertainty caused by variable soil moisture conditions significantly improved estimates of crop residue cover. These new techniques may be used to monitor the spatial and temporal changes in soil tillage intensity across landscapes and to identify where additional conservation practices may be required to both improve productivity and ecosystem services.

Peanut skin with wet distillers grains in cattle diets reduces methane at laboratory scale. Few studies have quantified, at laboratory scale, how cattle diets affect greenhouse gas emissions associated with the rumen microbiome and rumen fermentation activities. Scientists from ARS in Bushland, Texas, and Ames, Iowa, investigated the effects of adding wet distillers grains plus solubles and tannin-rich peanut skin to rumen fluid in laboratory containers. The tannin-rich peanut skin in the presence of wet distillers grains plus solubles suppressed the chemical pathways that create methane directly via antimethanogenic activity. These data will be used to fine tune dietary strategies that can reduce greenhouse gas emission for feedlot beef cattle and dairy cattle, while increasing the conversion of feed to meat.

Component 3. Reducing environmental risk of agricultural operations

This third component focuses on research that evaluates approaches to lower environmental risks from agriculture, especially generation, off-site migration, and ecosystem transport of chemicals (e.g., fertilizers or pesticides) and subsequent impacts on plant, animal, and human health. Environmental risks from agriculture can also include gases, odors, volatile organic compounds (VOCs), other airborne contaminants (e.g., particulates of less than 10μm [PM10]), pharmaceutically active compounds (PACs), pathogens, antibiotic-resistant bacteria, antibiotic-resistance genes, and heavy metals. Furthermore, contaminant generation and transport processes may be exacerbated by changing weather patterns attributed to climate change. Therefore, NP212 scientists conduct critical research helps understand the dynamics of, and reduce the presence and impacts of, these potentially hazardous contaminants in agricultural systems.

Selected Accomplishments

Decision support tool promotes adoption of precision agricultural practices on small and medium sized farms. Auto-guided tractors can reduce on-farm inputs by as much as 20 percent and save producers $10.8 to $13.5 million annually through gains in equipment efficiency and enhanced yields. Moreover, auto-guided tractors also help producers reduce the possible overapplication of fertilizers and herbicides, which in turn, reduces the negative environmental footprint of crop production and avoids unintentional input costs. ARS scientists in Fayetteville and Booneville, Arkansas, with University of Arkansas research partners, developed a decision support tool that promotes the adoption of precision agriculture technologies such as auto-guided tractors and other self-propelled machinery that reduce overapplication of on-farm nutrients and inputs by 10 to 20 percent. Their Tractor Guidance Analysis software incorporates parameters tailored for the size of different farming operations and generates estimates for 1) reductions in seed, organic and inorganic fertilizer, and chemical inputs given differing terrain attributes; 2) efficiency gains and feasibility of technology adoption by determining break-even prices based on farming operation type, farm size, and capital investment requirements; and 3) subsequent soil health and water quality effects from reduced agricultural inputs based on in-field data. This tool was released in 2018, and scientists have provided hands-on training to farmers and agricultural workers via field days and stakeholder meetings. The Tractor Guidance Analysis software has been especially effective in advancing the use of auto-guided tractors and self-propelled machinery on small farms, which have not traditionally adopted precision agriculture technologies.

Inexpensive vegetative buffers around poultry facilities reduces air pollution. Vegetative environmental buffers (VEBs) are composed of selected trees, shrubs, and/or tall grasses that are frequently installed near the exhaust fans of poultry houses to control and reduce the off-site transport of potential pollutants such as particulates and ammonia. The Natural Resource Conservation Service (NRCS) has historically developed guidelines and tools for the design and selection plants for VEBs, but the effectiveness of VEBs in controlling emissions has not been adequately quantified. ARS researchers in several locations (Florence, South Carolina; Beltsville, Maryland; Lubbock, Texas; and Ames, Iowa) in collaboration with colleagues at universities in Delaware, Iowa, Maryland, Oklahoma, and Alberta, Canada, used state-of-art laser systems and micrometeorological techniques to quantify dispersion and removal of particulates and ammonia from a poultry house surrounded by a vegetative environmental buffer. Particulate capture efficiency ranged from 20 percent to 70 percent depending on meteorological conditions, ammonia removal was 22 percent, and ammonia dispersion resulted in a net 51 percent decrease downwind. The NRCS is using these results to refine and bolster the standards that define the mitigation potential and limitations of the vegetative buffers.

Measuring the variability of microbial contamination in groundwater. Groundwater is often thought to move slowly underground and stay constant in its chemical and biological composition. This popular perception is untrue, especially for groundwater in aquifers with fractured bedrock. In the fractures, groundwater can move and change very quickly, behaving more like a river, with changes that happen over hours instead of months. In this type of dynamic aquifer, a one-time sample from a well does not accurately represent contamination potential. Scientists with ARS in Marshfield, Wisconsin, in collaboration with U.S. Geological Survey colleagues, solved this problem by designing the first automated sampler for collecting groundwater from private wells. The sampler is controlled remotely by telephone and can collect samples continuously over many days. In one private well with the autosampler installed, the concentration of some contaminant microorganisms, such as coliform bacteria, changed 100-fold in 1 day. This new autosampler will allow scientists to better characterize the vulnerability of private wells to contamination originating from dairy farms and other livestock facilities, which in turn, will enable improved policy and management decisions to conserve water quality for well owners.