FY2020 Annual Report
National Program 212 –Soil and Air

Introduction

The mission of the Soil and Air National Program (NP212) is to conduct scientific research that provides fundamental knowledge of soil-crop-air system dynamics and that helps develop technologies and practices producers can readily use to improve management of soil resources, reduce impact on air resources, efficiently use inputs, and contribute to ecosystems services. The vision for NP212 is productive and sustainable agricultural systems managed to optimize soil function and minimize impacts on air and water resources.

Background: U.S. agricultural production has seen enormous progress due to advances in scientific discovery, technology development, and efficient management. Despite such gains, agricultural supply chains continue to be challenged to increase production for a growing population and to do so through management that maintains farm efficiency and profitability, preserves natural resources, is resilient to changing climate, and instills public trust. The goals of NP212 are to help farmers meet their challenges through research that:

- develops practices and technologies for soil health and quality needed for crop production
- reduces atmospheric emissions that degrade air quality and contribute to climate change
- optimizes management of fertilizers, manures, agrochemicals, and byproducts for crop production and environmental protection
- develops options for resilient farm production systems facing climate change and extremes.

Healthy soil is the foundation for sustainable production, and the focus on its importance continues to increase. Benefits of healthy soils include more efficient nutrient cycling and pest control, and associated cost reductions and environmental benefits of reduced reliance on inputs. Healthy soils can help increase resilience to extreme weather, such as droughts and excessive precipitation, through increased soil moisture retention and better water infiltration. Healthy soils are also associated with reduced greenhouse gas emissions and climate change mitigation, both of which are driven by enhanced soil carbon sequestration. Research in NP212 strives to develop the practices and technologies that improve soil health and the metrics for how much soil health is improving. This is a broad need for the entire agricultural community, but especially for burgeoning ecosystem services markets that are interested in establishing financial incentives for producers to adopt sustainable management.

There is growing focus on how agricultural production contributes to greenhouse gas emissions including nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4) from soils, animal facilities, and manure storage and processing. There is also interest in reducing agriculture's impact on air quality due to emissions of odors, particulate matter, and gases such as ammonia (NH_4) and volatile organic compounds from agrochemicals. NP212 research intends to more accurately monitor and quantify agricultural atmospheric emissions and develop practices and technologies for producers to reduce emissions.

Agricultural landscape management and production practices are also linked to environmental emissions, such as nutrient and other agrochemical loss to surface and groundwater. A need also exists to address emissions and the fate of high-priority biologicals, including pathogens of concern and genetic elements that confer resistance to antibiotics. Agricultural production also represents an opportunity to beneficially use societal and agricultural byproducts to improve soils and/or to improve atmospheric conditions. NP212 research focuses on developing efficient and environmentally benign uses of inputs, as well as animal manures, to optimize production and minimize their negative effects on the environment.

Agricultural production is a systems process where few, if any, farm enterprises operate in isolation. NP212 research considers systems-level processes and develops systems-level practices and technologies (such as crop rotations that provide quality animal feed, improve soil health, and provide opportunities for efficient land application of manures) that are often the most attractive and relevant options for producers to adopt on their farms. This systems research requires a combination of both physical experimentation and simulation modeling, which in turn requires a team-oriented, multidisciplinary approach to research.

Activities and Impact: During FY 2020, NP212 had 83 full-time scientists working at 19 locations across the U.S. who were actively engaged in 23 ARS-appropriated projects supported by $45.6M in base funding for FY20. NP212 scientists initiated 16 new incoming collaborative agreements, and 15 new outgoing agreements. NP212 scientists also generated 162 peer-reviewed publications, 7 articles in trade journals, and 9 book chapters. There were also 144 students and post-docs training within NP212 research projects.

Personnel News for NP212

New scientists in NP212 in 2020:

- The Soil, Water, and Air Resources Research unit in Ames IA welcomed two new scientists in FY20**:** **Dr. Bryan Emmett** joined USDA-ARS after a Ph.D. degree at Cornell University and a postdoctoral position at the Boyce Thompson Institute in

Ithaca, NY. His research seeks to understand how cropping system management influences plant-associated microbial communities, their contributions to soil health, and the physiochemical and microbial controls on nitrous oxide emissions. **Dr. Claire Phillips** joined USDA-ARS after a Ph.D. degree at Oregon State University and employment with USDA-ARS in the Forage Seed and Cereal Research Unit in Corvallis, OR. Her research interests are crop management effects on soil physical quality, soil moisture dynamics, soil carbon cycling, and greenhouse gas emissions.

- **Dr. Brent Dalzell** joined the Soil & Water Management Unit, St. Paul, MN. He received his Ph.D. from Purdue University, followed by post-doctoral research at Old Dominion University and the University of Minnesota. His research interests are in watershed hydrology and soil biogeochemistry,
- The Adaptive Cropping Systems Laboratory in Beltsville MD had several visiting scientists in FY20: soil scientist **Dr. Ngowari Jaja**, came to ACSL via ORISE from her previous position as faculty in the Agriculture Department at the State University of New York in Cobleskill, NY. She is evaluating several industrial, municipal and agricultural byproducts that could be used in agriculture to improve soil fertility. **Dr. Zhuangji Wang**, Hydrologist, visited from China via University of Maryland. Dr. Wang's focus is to improve cover crop decomposition simulation in crop models. **Dr. Sanai Li**, an Agro-meteorologist from China visited via U.S. Forest Service International Visitors Program. Dr. Li's focus is on improving simulation of rice growth and development under U.S. production conditions. These improvements will be used to study climate and resource impacts, and identify management and phenotypic adaptation strategies in the Mississippi Delta. **Dr. Wenguang Sun**, soil scientist, visited from China via University of Nebraska. Dr. Sun's focus is improvement of photosynthesis and transpiration components of the soybean model, GLYCIM. This will allow for more realistic assessment of soybean management consequences on soil quality and water use in crop production systems in the United States. **Dr. Sahila Beegum**, was another visiting soil scientist, from India via University of Nebraska. Dr. Beegum's focus is improvement of photosynthesis and transpiration components of the cotton model, GOSSYM. This will allow for more realistic assessment of cotton management consequences on soil quality and water use in crop production systems in the United States**. Dr. Sonal Mathur**, a plant physiologist, visited ACSL from India, via ORISE. Dr. Mathur's work evaluated soybean cultivars from all the maturity groups on flowering response to changes in day length and temperatures. These data will be used to develop response functions for our soybean model, GLYCIM. This will improve soybean model's predictions at a range of environmental conditions and maturity groups. Finally, **Dr. Beomseok Seo**, plant physiologist, traveled from Korea via the University

of Washington. Dr. Seo's work focused on soybean flowering experiments and model development along with Dr. Mathur.

- **Dr. Patrick Ewing** joined the North Central Agricultural Research Laboratory, Brookings SD, as a postdoctoral research associate. Patrick holds a Ph.D. in Agronomy from the University of Minnesota, Twin Cities, and specializes in developing management strategies that improve the soil habitat for crops and microbes, with an emphasis on improving nutrient availability and nutrient storage. Patrick is working with Dr. Mike Lehman to evaluate a new DNA sequencer that measures crop microbiomes in near real-time, which should inform adaptive soil management.
- **Dr. Curtis Ransom** was hired as a Research Soil Scientist at the Cropping Systems and Water Quality Research Unit in Columbia, MO. Dr. Ransom received a Ph.D. from University of Missouri. His research will focus on Big Data, Artificial Intelligence, and machine learning for agronomic decision support.
- The Soil and Water Management Research Laboratory, Bushland TX, hired **Dr. Terra Campbell** as a Research Soil Scientist, Dr. Campbell received her Ph.D. from West Texas A&M University. Terra is studying soil changes in response to dairy manure applications. **Dr. Catherine Lockard** also joined SWMRL as a Research Animal Scientist. Dr. Lockard received her Ph.D. from Oklahoma State University, and is studying feed effects on enteric methane production by feedlot steers.
- The Hydrology and Remote Sensing Laboratory in Beltsville MD welcomed two postdoctoral research associates in 2020: **Dr. Nishan Bhattarai** comes from University of Michigan, where he was doing a post-doc. His expertise is Remote Sensing and he will be working primarily on ET models with Dr. Bill Kustas and general modeling/optimization with Dr. Glenn Moglen. **Dr. Audra Hinson** joined from Utah State University where she was a post-doc. Her expertise is watershed science. She will be working with Dr. Greg McCarty on the watershed lag time project and watershed modeling.
- The Environmentally Integrated Dairy Management Research Unit, Madison WI, hired a new postdoctoral research associate: **Dr. Joseph Heffron**, who is working with Dr. Tucker Burch, received a Ph.D. from Marquette University; his research focuses on quantitative risk assessment, primarily related to pathogens in water.

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

- **Dr. Rick Todd**, Research Soil Scientist in the Soil and Water Management Research Laboratory, Bushland TX, retired Sep 30, 2020. Dr. Todd's major accomplishment was the development of emission factors for ammonia for Southern High Plains.

- The Columbia Plateau Conservation Research Center, Pendleton OR, said farewell to two retiring scientists in 2020: **Dr. John D. Williams** and **Dr. Dan Long**.
- **Dr. John Sadler**, Soil Scientist and Research Leader of the Cropping Systems and Water Quality Research Unit in Columbia, MO, retired after 36 years with ARS. John is well known for his leadership within CEAP and LTAR and was ARS Senior Scientist of the Year in 2016.
- **Dr. Jerry Hatfield**, Director of the National Laboratory for Agriculture and the Environment, Ames IA, retired in 2020. Dr. Hatfield was well known as the first Director of NLAE and for his research on crop and soil water dynamics and environmental quality.

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 2020:

- **Dr. Dan Olk** of the Soil, Water, and Air Resources Research unit in Ames IA, received Lifetime Membership in the Humic Products Trade Association, in recognition of his 10 years of service as Science Advisor to this industry group.
- **Dr. Dexter Watts** of the Soil Dynamics Research Laboratory, Auburn AL, was named a Fellow of the American Society of Agronomy in 2020.
- Scientists from the Coastal Plains Soil, Water and Plant Research Center in Florence SC, received awards from the Federal Laboratory Consortium in 2020: **Drs. Matias Vanotti and Ariel Szogi** received the 2020 Excellence in Technology Transfer Award, Southeast Region, for "Recovery of Ammonia from Waste using Gas Permeable Membranes**." Drs. Vanotti and Szogi**, along with **Dr. Thomas Ducey**, also received the 2020 FLC National Award for Excellence in Technology Transfer for "Odor/Ammonia Capping of Swine Lagoons using High Performance Nitrifiers."
- In the Hydrology and Remote Sensing Laboratory in Beltsville MD, **Dr. Michael Cosh** was elected a Fellow of the American Society of Agronomy, and **Dr. Bill Kustas** received the American Geological Union Hydrologic Sciences Award, for "outstanding contributions to the science of hydrology."
- **Dr. Newell Kitchen** of the Cropping Systems and Water Quality Research Unit in Columbia, MO, received the Werner L. Nelson Award for Diagnosis of Yield-Limiting Factors from the American Society of Agronomy.

In FY 2020, 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 FY2020

The following sections summarize significant and high impact research results that address the components of the FY 2016-2020 action plan for NP212. Many of the programs summarized for FY2020 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 focuses on developing management approaches that promote soil health and stewardship. While "healthy" soils are difficult to quantitatively define, they are considered to be ones that maintain and even improve crop productivity as well as their resilience to climate disturbances (e.g., droughts, intense precipitation, temperatures extremes), diseases, and invasive pests that would negatively affect less "healthy" soils. Climate disturbances are a concern because they are increasing in frequency and intensity, and adversely affect both productivity and soil resources. In addition, healthy soils can moderate problems associated with wind and water erosion and their impact on production. NP212 builds on the foundational discoveries and 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 agricultural soils to perform under a wide range of conditions.

Selected Accomplishments

Precision agriculture has a new tool for creating soil carbon content maps. Soil carbon mapping is extremely useful in assessing the effect of land management practices that promote crop productivity, agroecosystem sustainability and ecosystem services. ARS researchers in Auburn, Alabama, have developed a unique mobile system that uses neutron-gamma analysis to assess and map soil carbon to a depth of 30 cm (plow layer) in real-time. The team coupled their mobile system to a Global Positioning System (GPS) device to simultaneously acquire soil carbon content and geographical positions for field mapping. The reliability of soil carbon measurements was demonstrated to be in good agreement with traditional soil sampling, well within the 95% prediction bands. The approach yields an efficient, geo-referenced tool to facilitate rapid, inexpensive and accurate construction of soil carbon maps. This methodology has been licensed for commercialization and will be useful to all crop producers, the national and global soil health community, such as NRCS, UN FAO Global Soil Partnership, and to university researchers and NGOs. It has potential applications for other soil assessment needs in the areas of construction and land restoration for the BLM and even the DOD.

Standardizing soil analysis provides an understanding of the soil microbiome and its relationship to soil health. Soil health is a complex concept that requires fundamental characterization of the living soil ecosystem. There is thus a critical need for reliable consistent scientific methods (such as microbiome analysis that depend on advanced DNA methods) to do that characterization. Standardization of protocols for sample collection and handling, laboratory analysis, and data collection and analysis is critical to reduce study variability, improve interpretation of results, and increase the utility of soil health assessments for developing better soil health management for productivity, sustainability, or resilience to climate change. A consortium of ARS scientists in Pendleton, Oregon; Fort Collins, Colorado; Brooking, South Dakota; Riverside, California; Columbia, Missouri; Fayetteville, Arkansas; Florence, South Carolina; Beltsville, Maryland; Lincoln, Nebraska; Stoneville, Mississippi; and Morris, Minnesota have developed such a protocol to address sources of variability and uncertainty in measuring microbial community composition and its connections with agricultural management and changing climate. Success in these areas is essential for deriving a "return on investment" for managers considering a shift to soil health-promoting practices. The tools and data are important to the soil health community within the United States, the global community (e.g., the United Nations FAO Global Soil Partnership), and researchers from public and private institutions worldwide who are interested in applying information on the genetic potential of soil to enhance soil ecosystem sustainability.

Stacking management practices improves soil health. Linking specific management practices to measurable changes in soil properties is a key objective for increasing adoption of those practices to improve soil health. ARS scientists in Brookings, South Dakota used two long-term field studies to show how adding, or stacking, new practices to base management can affect soil structure and microbial activity. Both studies had base management that included no-till. In one study, crop rotation diversity was added as a new practice, and in the second study, crop residue retention and cover cropping were added. How much added managements changed measured soil properties often depended on when in the crop rotation samples were taken, showing that stacking management is not simply additive. However, there was never a negative effect of stacking soil health building practices to the no-till crop systems. Implementing multiple positive management tactics increases the likelihood that improvements in soil properties related to better health can be measured. This information is valuable to scientists researching related topics, to extension personnel advising producers, and to producers selecting management tactics as part of their strategy to increase their ecosystem services.

Enhancing crop yields with beneficial crop symbionts. ARS researchers in Wyndmoor, Pennsylvania developed molecular tools to identify, quantify, and characterize 11 species of agriculturally relevant arbuscular mycorrhizal fungi (AMF) to enable the selection of ones most beneficial for crops. Previously, this team had developed methods for on-farm production of mixed-species AMF inoculum, which, when applied to seedlings, increased yield of several crops (including strawberries, tomatoes, eggplant, peppers, potatoes, and leeks). However, neither the measurement of, nor the determination of impact of individual species was possible. The team then developed quantitative PCR (qPCR) detection assays for 11 different species of AM fungi found in agricultural soils - assays that enable the identification and quantitation of the fungi directly from soil samples and in plant root tissues, enabling spore enumeration from soil samples within a single workday, compared to the previous assessment approach that took more than a month to complete. Prior to the development of these assays, identification of AM fungi required isolation of spores from the soil and observation of morphological features by microscopy, followed by confirmation through PCR and DNA sequencing. Furthermore, the qPCR method enables direct measurement of colonization efficiency of individual AMF species on plant roots, which was not previously possible, and provides an indication of which AMF species are likely to have the most beneficial impacts on crop productivity. These advanced tools will help to improve agricultural sustainability by guiding the selection of species of AM fungi for propagation and development as AMF biofertilizers – products that improve nutrient acquisition and water uptake and reduce susceptibility to pathogens and disease.

Conservation tillage rebuilds surface soil organic carbon and nitrogen contents. Conservation tillage is an effective management strategy to rebuild soil organic carbon and total nitrogen levels. However, there are few long-term studies available to quantify either the rate of change or measurable benefits. ARS researchers in Florence, South Carolina, created a long-term tillage and crop management experiment using sandy soils. Topsoil samples were collected annually over 37 years under conservation and conventional tillage, and organic carbon and total nitrogen contents were measured. Topsoil under conservation tillage had a 23% more organic carbon and 16% more total nitrogen than topsoil under conventional tillage. Furthermore, both tillage systems seem to have reach a new equilibrium where total organic carbon is no longer increasing. These unique results obtained over nearly four decades will help landowners and greenhouse gas technical assistance providers determine the climate value and amount of carbon credits from implementing conservation tillage practices under new USDA carbon credit programs.

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 NP212 scientists will enable agricultural producers to optimize their use of nutrients, save money, and lower losses to the environment.

Selected Accomplishments

Strategic management using new and improved decision tools can improve farm productivity and environmental impacts. Producers and researchers need decision-making tools to estimate how their production decisions influence farm productivity and environmental impacts. ARS researchers in Fort Collins, Colorado collaborated with Colorado State University to develop the CaRPE model and upgrade the DayCent model. CaRPE is an interactive management tool that couples crop and grazing land data from the Ag Census (USDA-National Agricultural Statistics Service) with county-level Greenhouse Gas (GHG) emission reduction coefficients. CaRPE has been used to explore the regional and national potential for agriculture to reduce GHG emissions and combat climate change, and the output has been shared by American Farmland Trust in testimony before the House Select Committee on the Climate Crisis. The COMET-Farm tool, which imbeds algorithms from the DayCent model is increasingly used for field and farm productivity and GHG estimation and provides much of the modeling power of the CaRPE tool. ARS researchers improved DayCent by accounting for soil freeze-thaw effects on nitrous oxide (N_2O) emissions; representing soil organic matter dynamics to 30 cm depth; addressing the effect of cover crops on GHG emissions and removals; better resolving the timing of tillage, planting, fertilization and harvesting based on the USDA-NRCS CEAP survey and state information on planting and harvest dates; improving the timing of irrigation; and when crops will senesce based on locally relevant temperature trends. These changes resulted in an increasing the accuracy of GHG emissions and a more accurate estimate where GHG emissions were 22 percent higher from 1990 to 2017 relative to the previous inventory. Both models will enhance the ability of farmers to manage their systems, provide better estimates of and strategies to control GHG emissions, and provide a better foundation for additional scientific discoveries and agricultural management. The tools are useful to producers, researchers, to NGOs such as the American Farmland Trust, the U.S. Climate Alliance, the Nature Conservancy, and others, as well as to government organizations including but not limited to the NRCS, the EPA, and NOAA.

Phenol accumulation in California rice soils correlates with late-season inhibition of crop nitrogen uptake. A key factor of rice grain yield is late-season crop uptake of soil nitrogen, which promotes grain filling. Previous ARS research in experimental rice plots in Arkansas found that inhibition of late-season crop nitrogen uptake was correlated with soil phenol contents. Recently, ARS researchers in Ames, Iowa, collaborated with the University of California, Davis to analyze soil from fields on working farms in the Sacramento Valley that varied widely in late-season rice uptake of nitrogen. Soil phenol concentrations were moderately correlated with the late-season rice nitrogen uptake, providing first-time, on-farm evidence to strengthen the previous ARS findings from Arkansas. Variation in soil phenol content may be caused by differences in how fields are aerated during the season. The basis for increased soil aeration arose partially from the ARS rice research in Arkansas, which is now being studied in additional rice-producing states in the United States. The practice of increased soil aeration has also been incorporated into the Sustainable Rice Platform, which is a global organization composed of more than 100 institutional members. It is striving to improve rice management practices of one million small farmers worldwide.

Strategies to decrease the causes of nitrous oxide emissions from beef cattle feedyards. Nitrous oxide is a potent greenhouse gas that has been linked to climate change. Elevated nutrient concentrations make livestock manure a source for nitrous oxide production. Scientists from Bushland, Texas, Clay Center, Nebraska, and Texas A&M AgriLife Research (Amarillo, Texas) investigated how weather affects nitrous oxide emissions from commercial beef cattle feedyards. They determined that nitrous oxide emissions were greatest under warm temperatures and shortly after rainfall events. The team determined that producers and regulatory personnel could better manage these emissions when they can better couple weather patterns with the weather-mediated nitrous oxide emissions from animal agriculture. The researchers also developed an empirical model to assess the effect of manure removal frequency on annual nitrous oxide emissions as related to these conditions. These data and tools that are in development will be useful for updating national greenhouse gas emissions inventories for beef cattle feedyards. In addition, an import the bottom line for producers, the cost of managing on-farm nutrients, can be improved for increased manure value.

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 may 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

New, agriculturally focused collection of *E. coli* types for enhanced animal and food safety. *Escherichia coli* is a bacterial species commonly isolated from both humans and animal as an indicator of fecal contamination of water supplies and environments, and more than 700 types (e.g., serotypes) of *E. coli* have been identified. Although most *E. coli* serotypes found in the phases of animal production are harmless, they have been shown to be a source and reservoir for antibiotic resistance genes that may be transferred to animal or human pathogens. Such antibiotic resistance is a significant concern for the health of producers, their animals, and the public at large, so understanding their differences will help in identification and mitigation strategies. Most *E. coli* collections focus on human health and very few collections represent the genetic variability and virulence of those affecting U.S. food animal production. ARS researchers in Florence, SC, led the assembly of a publicly available collection (referred to as AgEc) that identified and studied 300 *E. coli* variants found in four major animal production commodities – beef, dairy, poultry, and swine. This was a collaborative effort of 15 researchers - from nine ARS research units, universities and NRCS partners – and addressed production systems across 12 states. The team tested the collection members for resistance genes to two common antibiotics – tetracycline and sulfonamide. Analysis of antibiotic resistance gene patterns revealed significant differences along commodity and geographical lines. This AgEc effort provides a new publicly available database useful to producers, as well as food- and animal- inspection communities about the types and distribution of *E. coli* antibiotic resistance in animal production farms. It will assist in determining sources of fecal contaminants in water systems, food, and environments.

Groundwater quality in Upper Midwest is affected by both human and dairy pollutants. The groundwater aquifer in Northeast Wisconsin is vulnerable to contamination because it has thin overlying soils that allow contaminants from the land surface to move rapidly to the water table. Wastewater from septic systems and livestock manure from farming operations are possible contaminant sources. ARS researchers at Marshfield, Wisconsin, up to 28% of private wells in Kewaunee County had detectable coliform bacteria (an indication of fecal contamination) or nitrate-N concentrations greater than 10 mg/L. Furthermore, pathogens that cause illness in people were present in private wells, and both human wastewater and cattle manure were identified as sources of fecal contamination in contaminated wells. ARS researchers also used a comprehensive lab approach to test 964 samples from 145 wells supplying public water systems in Minnesota and found that fecal contamination was present in 58% of samples and 96% of wells. They also found that simple tests used by public water systems for bacteria indicative of fecal contamination were good at predicting pathogen absence, but not pathogen presence, and would not be reliable for estimating illnesses from drinking fecal-contaminated groundwater. These findings are providing opportunities for communities in the region to understand the extent of water contamination by human and animal pathogens and improving clean groundwater for the residents.

New poultry manure amendments reduce environmental impacts. Ammonia gas emissions from poultry houses and phosphorus loss in runoff from fields where litter (manure + bedding) is applied are two environmental problems from poultry production. Because spreading alum in poultry houses reduces both these problems and improves bird health, the practice is used for about 40% of the broiler chickens in the U.S. Recently, however, adding alum has not reliably reduced litter soluble phosphorus as much as in the past. In fact, adding alum increased soluble phosphorus in litter that had been treated with sodium bisulfate, a popular ammonia-control product. ARS researchers in Fayetteville, Arkansas, discovered that adding small amounts of calcium-based nanoparticles to litter treated with alum and/or poultry litter treatment caused a synergistic reaction that resulted in very low soluble P. The researchers also found that treating litter with alum mud, which is a byproduct remaining after alum manufacture, reduced ammonia emissions and from poultry litter by 27% to 52%, which was not significantly different from alum (35%). The presents a sustainable use for the alum mud byproduct, which is currently being landfilled at a cost of $32 per ton. These combined practices of using alum, nanoparticles, and alum mud could be applied to 80% of the broilers in the U.S. to improve bird health and reduce environmental impacts.

New method rapidly quantifies field spatial overlaps and gaps for precision agriculture tools. Auto-guided tractors can reduce on-farm inputs by as much as 20% and nationally save producers $10.8-13.5 million each year by improving equipment efficiency and enhancing yields. Less application of fertilizers and herbicides can also reduce potential losses to the environment. About half of large-scale crop producers are using tractor guidance; but 82% of U.S. farms are small farms that are largely not adopting these cost-saving and environmentally sound technologies. ARS researchers in Fayetteville and Booneville, Arkansas, in collaboration with the University of Arkansas, developed a novel automated method to rapidly determine spatial overlaps (up to 6% of the total field area) and gaps (up to 16% of field area) in machinery coverage and how much precision technologies, such as auto-guided tractors and other self-propelled machinery, can reduce those overlaps and gaps. Tractor guidance systems during field operations improve the average overall efficiency by 8%, reducing input use and in-field operation time. This novel approach of estimating tractor guidance efficiency on small farms using production fields can aid in adoption of tractor guidance, thus potentially improving efficiency gains on 82% of U.S. farms.

New economical and efficient strategies remove antibiotics from wastewater and increase agricultural safety and human health. Understanding the removal mechanism of antibiotic compounds and antibiotic resistance determinants in agricultural systems is a global challenge that is important in the protection of human health. An ARS researcher from Riverside, California, and collaborator from University of California, Riverside, designed and tested a system of layered environmental media (consisting of gravel, sand, soil, and a “soil plus biochar” combination) through which antibiotic-laden water was pumped. Overall removal efficiencies of four tested antibiotics - amoxicillin, cefalexin, sulfadiazine, and tetracycline - were 81, 91, 51, and 98%, respectively. If the exposure time was lengthened, the removal efficiency was increased, especially for amoxicillin and cefalexin. Overall, the results from this lab-scale proof of concept system indicate the potential of the system for antibiotic removal from wastewater and highlight ways in which improvements to removal efficacy may be scalable for broad applicability. The results of this study will be used by wastewater treatment facilities, World Health Organization, researchers, and other local municipalities in many developing countries.

New research targets less enteric methane emissions from cattle. Cattle produce the greenhouse gas methane as a natural byproduct of digestion, and researchers are investigating ways to help reduce these enteric methane emissions. ARS scientists from Bushland, Texas, Woodward, Oklahoma, and El Reno, Oklahoma, in collaboration with Texas A&M AgriLife Research, studied how cattle methane emissions were affected by hay nutritional quality and fiber content. Cattle fed a high-quality hay diet (high crude protein) produced less methane per unit of digested organic matter than when fed low-quality hay. ARS researchers at Bushland, Texas, and Ames, Iowa, also showed that adding tannin-rich peanut skin, which is a common by-product in the region, in cattle diets can suppress rumen microbial methanogenesis. This research is showing both scientists and producers the multiple benefits of feeding higher quality hay to improve animal performance and reduce emissions, and what feed additives may provide cost-effective mitigation of enteric methane from beef and dairy cattle.

Pulverized wastepaper helps rehabilitate military training lands. The United States Army produces a significant amount of classified paper waste that is pulverized to a fine consistency unsuitable for recycling. However, this cheap, high quality organic material can be useful as a soil amendment. ARS researchers in Auburn, Alabama, working with the U.S. Army Corps of Engineers developed technology to use pulverized wastepaper to rehabilitate military training lands. Application of paper waste to soils had no adverse environmental effects, improved soil physiochemical properties, and improved establishment of desirable native vegetation. When combining cost savings associated with landfill disposal of the paper with savings from greater land rehabilitation success, an estimated $300 per ton of diverted paper is realized. At the recommended application rate, this results in a cost savings of approximately $4,700 per acre. At the installation level, this equates to an estimated annual costs savings of $20,000 with 70 tons of paper diverted.