USDA-ARS National Program 216- Sustainable Agricultural Systems
Annual Report for FY2023

Introduction

Fiscal year 2023 research supported the 2023-2027 Action Plan for National Program (NP) 216. The Action Plan and the projects were developed from comprehensive stakeholder input gleaned from national stakeholder listening sessions.

Vision

Integrated solutions for agriculture enabling greater productivity, profitability, and natural resource enhancement.

Mission

The mission of NP216 is to build the science-based foundations for farming systems of the future using a systems approach without bias for particular science discipline. Producers will be equipped with actionable genetic and management options offering multiple routes to achieving the four goals of sustainable agriculture: 1) desired quantity and quality of yields, 2) economic viability and competitiveness, 3) environmental enhancement, and 4) quality of life for rural populations and society as a whole.

This transdisciplinary research effort integrates information and technology. New configurations of practices will be identified that integrate on-farm resources with knowledge of natural ecosystem processes to reduce the need for purchased inputs, thus reducing production costs and risk. Technological advances that include precision management, automation, and decision support tools are investigated to increase production efficiencies and enhance environmental benefits. The resulting diverse, improved agricultural systems will support the long-term financial viability, competitiveness, and sustainability of farms and rural communities, and increase food, feed, and fiber security for the U.S. and the world.

Approach

NP216 is organized into three components:

- Building Agroecosystems for Intensive, Resilient Production via GxExM
- Increasing Efficiency of Agroecosystems
- Achieving Agroecosystem Potential

These three component areas focus on what can be implemented to improve production efficiency within the field, what can be done to limit the offsite impact and enhance ecosystem services, identify the limitations to productivity, sustainability, and resilience of agricultural systems, and integrate knowledge gleaned to optimize agricultural systems at the field and farm scale.

2023 News for NP216

Many of the NP216 projects include significant domestic and international collaborations including government, industry and academia. These collaborations provide opportunities to leverage funding and scientific expertise for USDA-ARS research and accelerates dissemination of ARS research results, thus enhancing the impact of ARS research programs. During 2023, NP216 scientists participated in research collaborations with scientists from Argentina, Australia, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Hungary, India, Iran, Ireland, Israel, Italy, Kuwait, Mexico, Mongolia, Netherlands, New Zealand, Romania, South Africa, South Korea, Spain, Sweden, Taiwan, Tunisia, and United Kingdom. In FY2023, 116 full-time scientists working at 26 research units across the U.S. actively engaged in 34 ARS-led and 242 collaborative research projects. Base program funding was $82.6M.

Personnel news for NP216

New additions to the NP216 team in 2023 were:

- Agricultural Engineer **Dr. Kelly Thorp** has moved from the U.S. Arid Land Agricultural Research Center in Maricopa AZ, to the Grassland Soil & Water Research Laboratory, Temple TX. His expertise has largely been with determining evapotranspiration from irrigated cotton. In Temple, he will be an invaluable member of the National Agroecosystem Model (NAM) team that supports the Conservation Effects Assessment Project and other national and international resource assessments.
- **Dr. Curtis Ransom** joined the Cropping Systems and Water Quality Research Unit, Columbia, MO, as a Research Soil Scientist, in August 2023. Dr. Ransom was previously a postdoctoral research associate at CSWQ and received his PhD from the University of Missouri. His research focuses on soil fertility, especially nitrogen management, advanced methods for soil carbon measurement, and applications of data science. CSWQ also welcomed visiting scientist Stirling Roberton in 2023. Dr. Roberton is a Research Scientist with CSIRO in Australia. While at CSWQ his research focused on identifying soil factors limiting crop production and ecosystem services using a Digital Soil Mapping approach. CSWQ received two new postdoctoral research fellows in 2023: Divya Kandanool is a soil scientist who completed her PhD at Arkansas State University;

Namitha Pais is a statistician who completed her PhD at the University of Connecticut. Both Divya and Namitha are conducting research contributing to a national soil health tool, Soil Health Assessment Protocol and Evaluation (SHAPE).

The following scientists left the ranks of NP216 in 2023:

- Dr. Jim Kiniry retired from the Grassland Soil & Water Research Laboratory, Temple TX.
- Dr. Newell Kitchen, Research Soil Scientist, retired from the Cropping Systems and Water Quality Research Unit, Columbia, MO. Dr. Kitchen has been internationally recognized for his research in soil fertility, cropping systems and precision agriculture. He is a past president of the American Society of Agronomy.

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

The quality and impact of NP216 research was evidenced during FY2023 by the following:

- 184 refereed journal articles and four book chapters published;
- 36 new incoming agreements with collaborators and 73 outgoing agreements;
- one new invention disclosure submitted; and
- 97 students and postdoctoral research associates training with ARS.

Selected Research Accomplishments for FY2023

Component 1. Building Agroecosystems for Intensive, Resilient Production via GxExM

Root-zone enrichment of soil organic matter improves with conservation management. The historic loss of soil organic matter from intensive tillage in the southeastern United States can now be remediated with conservation management systems that sequester carbon. An ARS scientist in Raleigh, North Carolina, collected soil from different land uses on 25 research stations across North Carolina to determine the potential of surface soil to store carbon from conservation management with either no-till cropping, grassland management, or timber production. The results suggested that conservation management was a beneficial strategy to improve soil organic carbon and total soil nitrogen of surface soils throughout North Carolina. Soil texture was an important co-factor but did not negate the positive impact of conservation management anywhere in the state. Woodland and grassland management were more effective at storing carbon and nitrogen than no-till cropland. These results will be important for agricultural advisors, farmers, extension specialists, and scientists in the region to promote more efficient, carbon-storing practices for agriculture to simultaneously meet the production and environmental demands needed to achieve a sustainable future.

Scientists identify hibiscus, okra, and teaweed as alternate plant hosts for cotton leaf-roll dwarf virus (CLRDV). Identifying alternate host plants that can act as virus inoculum sources and vector reservoirs in the landscape is critical to understanding virus epidemics and mitigating disease spread. Cotton leafroll dwarf virus (CLRDV), a serious pathogen in cotton production, is transmitted by the cotton/melon aphid, but more information was needed about the role of alternate plant hosts in CLRDV establishment. ARS researchers in Auburn, Alabama, and University of Georgia and Auburn University collaborators examined 14 common plant species in the landscape to determine their potential as alternate hosts of CLRDV via aphid transmission assays. CLRDV was detected following inoculation in hibiscus, okra, palmer amaranth, and teaweed. Aphids feeding on CLRDV-infected teaweed, hibiscus, and okra alone were able to acquire CLRDV and transmit it back to non-infected cotton seedlings. This study demonstrated that plant hosts in the agricultural landscape can serve as CLRDV inoculum sources and as aphid reservoirs that may contribute to reoccurring CLRDV epidemics in the southeastern United States. Correctly identifying potential hosts and/or aphid reservoirs for CLRDV will be critical to developing future CLRDV control strategies.

Improving the long-term effectiveness of agricultural conservation practices on Chesapeake Bay health. Implementing agricultural best management practices over the past decade has often failed to meet pollution reduction goals in the Chesapeake Bay watershed. ARS scientists in University Park, Pennsylvania, and Penn State University collaborators leveraged a technique called Lorenz Inequality, which is commonly used in economics to quantify income inequality, to assess why agricultural practices were not meeting targeted results. They found that a large majority of annual loads are transported during short time periods associated with high-flow events, while conservation practices are often most effective during smaller events. The prevalence of concentrated flow pathways (erosion channels) in riparian buffers allows stormwater to be “short-circuited” through these buffers, reducing their potential to mitigate pollutants. In addition, stream segments assessed before and after buffer implementation did not show consistent improvement in macroinvertebrate diversity, which makes it difficult to de-list these streams from the impaired list. Multi-zone buffers that position grass between the crops and forested section of a buffer help improve buffer effectiveness and reduce the potential development of concentrated flow pathways. Three peer-reviewed manuscripts provide the data analysis and decision-making tools necessary for enhancing spatial targeting of conservation practices with a temporal targeting component. By better understanding the temporal variability of nutrient and sediment loads, solutions can be proposed that enable targeting to move from the “right practice in the right place” to the “right practice in the right place at the right time.”

Cover crops benefit soil water availability and weed control. Cover crop interseeding, which refers to planting a cover crop into a standing cash crop to promote earlier establishment, can increase biomass production, which helps improve rain infiltration and reduce evaporation from soil. Soil water data collected for 4 years as part of the Cover Crop Systems Project at Beltsville, Maryland, indicated that soil water storage during the corn growing season was 10 to 20 mm (0.4 to 0.8 inches) greater in systems with interseeded cover crops than with no cover crop. Corn grain yields during 4 years were on average 24 bu/a (1.5 Mg/ha) greater with a cover crop, and average water use efficiency was also greater with a cover crop. Increased yield profits were more than sufficient to cover the cost of establishing cover crops and demonstrate the benefits of interseeded cover crops in U.S. humid regions. In other research, ARS researchers in Auburn, Alabama, conducted a 2-year field experiment to assess how a high biomass crimson clover cover crop and conservation tillage affect the critical timing of weed control (CTWR) and the critical weed free period (CWFP) in corn. The presence of a crimson clover cover crop delayed the CTWR and advanced the onset of CWFP, which reduced the time needed for weed control. During most of the growing season in both years, conservation tillage plus clover reduced weed biomass production more than in conventional tillage plots or conservation tillage with winter fallow. As research quantifies additional benefits of cover crops for improving soil water availability through increased water infiltration and the control of herbicide-resistant weeds, this will enable agricultural producers and policymakers to make informed decisions about implementing cover cropping practices.

Repurposing legacy data for new uses. Many ARS locations and state experiment stations have crop and rangeland livestock production experiments that have lasted for more than 10 years. Information from these experiments could be used to help to understand responses to climate change, model crop and livestock production, or determine how vegetation changes affect livestock production. However, this valuable information is often recorded on handwritten sheets that are stored in file cabinets, which limits their use by other scientists. ARS scientists in Mandan, North Dakota, and Fort Collins, Colorado, started a project to digitize this data and store it at the National Agricultural Library (https://data.nal.usda.gov/LTLiveProd). Currently, the team has helped digitize and store seven different long-term datasets that range from 100 years of cattle weight gains from Mandan, North Dakota, to 12 years of pregnancy rates, calf weaning rates, and sale prices from the University of Nevada Agricultural Experiment Station in Austin, Nevada. Datasets include information from ARS and state experiment stations and cattle and sheep data. These long-term data sets are extremely valuable and efforts to preserve and make them more accessible are essential so scientists can use historical data to solve future problems.

Soil microbial networks help soybeans respond to ozone pollution. Soybean is a major U.S. export crop with a total export value at $34 billion in 2022, and it is especially susceptible to ozone. As ozone pollution and warming substantially worsen, U.S. soybean yield is projected to decline 28 percent by the year 2050. To optimize crop yield for a growing global population and maintain healthy agricultural ecosystems, ARS researchers in Raleigh, North Carolina, identified a soybean cultivar that is tolerant to elevated ozone pollution and used genomic sequencing technology to identify soil microorganisms that might assist this cultivar in adapting to elevated ozone pollution. The study identified symbiotic bacteria and fungi associated with soybean nutrient allocation. The findings demonstrated that while ozone does not penetrate soil, ozone can affect soil microbial communities through plant-mediated processes in the root zone. Symbiotic bacteria supporting plant ozone adaptation could potentially be developed into biofertilizers that can enhance crop performance and improve agricultural ecosystems under environmental stress.

Component 2. Increasing Efficiencies for Agroecosystem Sustainability

Conservation practices improve soil health and provide economic benefits to farmers. Adopting conservation practices has been hampered by the lack of regionally relevant soil health information and lack of a demonstrated relationship between soil health measurements and crop yields. ARS scientists in Columbia, Missouri, and University of Missouri collaborators collected data from more than 5,300 production fields in Missouri, and showed that biological and physical soil health status was greater in systems with increased rotational diversity (three or more crops) and reduced tillage. In related work with public and private partners, they used data collected from 96 farms in 9 Midwestern states for 5 years to link soil health scores to corn and soybean yield and demonstrated improved soil health had economic benefits. Furthermore, Missouri data indicated soil health variability within a field was linked to corn yield, and a threshold level of active carbon, a popular soil health indicator, was identified for optimal corn grain productivity. These results support farmers by providing them with science-based information on the economic and soil health benefits of conservation management practices.

New tool helps California specialty crop producers adapt to climate change. Climate change is projected to challenge California's agricultural production, and its specialty crop industry may be uniquely vulnerable to warming winters and increasing water demands. ARS scientists at the USDA California Climate Hub in Davis, California, created the Adaptation Resources Workbook for California Specialty Crops. The workbook provides science-based information and a multi-step process for developing a farm management plan that explicitly incorporates climate adaptation. Throughout the workbook, resources such as Cooperative Extension guides, Natural Resources Conservation Service technical documents, and scientific literature offer a scientific basis for the workbook's adaptation menu, which offers a non-exhaustive list of climate-adaptive actions that producers can use to adapt their operations to the effects of climate change.

Predicting cotton fiber quality. Cotton fiber quality is a major economic concern for U.S. growers. While both cotton yield and quality are influenced by climate, soil, and management, decision support tools for cotton have primarily focused on yield. ARS scientists in Beltsville, Maryland, incorporated a cotton fiber quality modeling methodology into the existing ARS GOSSYM cotton model, which enables the model to predict how growth temperature and plant water and nutrient status will affect fiber micronaire (fiber fineness and maturity), staple length, uniformity, and strength. This inclusion of fiber quality is unique to cotton modeling and decision support efforts and can be a valuable tool for determining cotton fiber quality and optimizing production/fiber quality under varying environmental and management conditions.

Component 3. Reaching Agroecosystem Potential

Improving watershed management planning, implementation, and outcomes. A scientifically rigorous and detailed watershed management plan is critically important for successfully restoring an impaired waterway. When stakeholders are involved in model development, scenarios better reflect stakeholder preferences, which increases the likelihood the plan will be successfully implemented. ARS scientists in University Park, Pennsylvania, and collaborators published four peer-reviewed papers providing several examples of successful engagement with local stakeholders that resulted in watershed management plans that reflected stakeholder inputs/values and achieved nutrient and sediment load reduction goals. These goals were achieved in several ways, either by prioritizing low implementation costs at the watershed scale while meeting load reduction goals or prioritizing watershed yields by modifying where crops were grown (a functional land management approach). These papers provide examples of stakeholder engagement processes that were successful in developing each management plan, and documented the water quality benefits of those plans compared to other more traditional approaches that do not take stakeholder preferences into consideration. In each case study, water quality goals were achieved or exceeded when incorporating stakeholder engagement into computer-based approaches.

Interactive tool quantifies the climate benefits of conservation management practices. Conservation agricultural practices have the potential to reduce greenhouse gas emissions, and recent legislation has expanded USDA's capacity to provide conservation practice incentives through programs like the Conservation Research Program (CRP) and the Environmental Quality Incentives Program (EQIP). Implementing these practices must be balanced with the need to produce food, fiber, and fuel for a growing global population. To provide land managers, producers, and researchers estimates of greenhouse gas reduction potential from the implementation of climate-smart practices, ARS researchers in Corvallis, Oregon, and Fort Collins, Colorado, developed the Carbon Reduction Potential Evaluation (CaRPE) tool. CaRPE is a web-based, interactive tool that visualizes and estimates how implementing conservation practices on croplands and grazing lands will help mitigate the agricultural sector's contribution to climate change. This tool allows users to build and export state, regional, or national scenarios based on the adoption of new conservation practices for desired acreages and locations. This tool is available at https://carpe.shinyapps.io/CarpeTool/ or through the Northwest Climate Hub and is being used to quantify the climate benefits of USDA conservation programs.

"Living filter" cannot reduce PFAS levels to proposed standards. Reusing treated wastewater for irrigation is becoming increasingly widespread to reduce reliance on freshwater resources for agricultural production. However, emerging contaminants, such as pharmaceuticals and personal care products (PPCPs) and per- and polyfluoroalkyl substances (PFAS), can persist despite conventional wastewater treatment technologies and are inadvertently introduced into agricultural fields when treated wastewater is used for irrigation. The Pennsylvania State University main campus has its own water reclamation facility that treats all campus wastewater for beneficial reuse at an agricultural and forested mixed-use site known as the "Living Filter." The facility has been operating at full-scale for more than 40 years. ARS scientists in University Park, Pennsylvania, and Penn State University collaborators monitored the presence of PPCPs and PFAS in the wastewater influent, effluent, and 13 groundwater monitoring stations at the site. The results showed that the Living Filter significantly mitigates PPCPs before water percolates to groundwater; concentrations are up to two orders of magnitude lower in the groundwater compared to the wastewater effluent. However, results indicate the filter cannot reduce PFAS concentrations below existing state and proposed federal drinking water standards. These findings indicate long-term use of treated wastewater as an irrigation source may not be feasible if PFAS levels remain elevated in the treated effluent.

Perennial bioenergy crops help store more carbon in the soil. Perennial grasses are potential bioenergy feedstocks that might help improve soil health by sustaining soil biology, because they have extensive root systems and provide continuous ground cover, but it takes multiple years of perennial grass production to obtain these soil health benefits. ARS scientists in Sidney, Montana, evaluated how two perennial grass species grown with varying nitrogen fertilizer rates for 11 years affected soil microbial communities compared to annual spring wheat (WH) grown with a typical amount of nitrogen fertilizer. Perennial grasses evaluated were intermediate wheatgrass (IWG) and switchgrass (SG) and each species was grown with nitrogen fertilization rates ranging from 0 to 84 kg N per hectare. Arbuscular mycorrhizal fungi (AMF) form a symbiotic association with plant roots and enhance the plant's access to water and nutrients. The researchers found that adding more nitrogen reduced AMF and increased the proportion of bacteria correlated with carbon degradation, so the lower-input system was better. Both perennial grass species enhanced AMF and the type of bacteria related to greater carbon storage compared to WH, and SG promoted these beneficial microbial groups more effectively than IWG. Results from this study will help growers select bioenergy perennial grass species and nitrogen fertilizer rates that optimize soil biological health and enhance sustainable production.