USDA-ARS National Program 216- Sustainable Agricultural Systems
Annual Report for FY2022

Introduction

Fiscal year 2022 research supported the 2018-2022 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.

2022 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 2022, 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 FY2022, 112 full-time scientists working at 27 research units across the U.S. actively engaged in 32 ARS-led and 197 collaborative research projects. Base program funding was $72M.

Personnel news for NP216

New additions to the NP216 team in 2022 were:

- **Dr. Lauren Breza** joined the Forage, Seed, and Cereal Research Unit (Corvallis, OR) as a HQ funded postdoc to work on the influence of tile drainage on carbon cycling. Lauren Breza graduated from University of New Hampshire. Her area of expertise is in nitrogen cycling. Her Ph.D. research focuses on soil ecology in agroecosystems and explores ideas around nutrient cycling and plant-microbe-soil interactions.
- **Dr. Clint Mattox** was hired as a Research Weed Scientist in the Forage, Seed and Cereal Research Unit (Corvallis, OR). He received his degree from Oregon State University. Clint Mattox work focuses on weed control in seed cropping systems. His area of expertise is on turf agronomy.
- The National Laboratory for Agriculture and the Environment, Agroecosystems Management Research Unit (Ames IA) hired **Dr. Sabrina Ruis** as a Soil Scientist. She investigates the effects of agricultural management practices on C and N cycling and soil health. Dr. Ruis worked as a Post-Doctoral Research Associate and Research Assistant Professor, University of Nebraska-Lincoln, Agronomy and Horticulture Department.
- **Dr. Courtney Hammond Wagner** was hired as a Research Social Scientist in the Food Systems Research Unit (Burlington, VT) to pursue social science research to address how small to mid-sized farms and food businesses can improve the sustainability and economic vitality Northeast food systems. Dr. Wagner came to USDA-ARS from Stanford

University. Her area of expertise focuses on how irrigation districts balance the competing demands of economic viability and environmental impact in the context of climate change manage natural resources in the economic, social, and policy contexts in which such decisions are made.

- **Dr. Sarah McCord** was hired as a Research Ecologist at the Range Management Research Unit (Las Cruces NM). Dr. Sarah McCord received her PH. D from the University of Texas, El Paso and ARS, Data Science/Informatics/Monitoring tools.
- **Dr. Prasad Bandaru** has joined the US Arid-Land Agricultural Research Center (Maricopa, AZ) as a Research Plant Physiologist. Dr. Prasad Bandaru earned his Ph.D. in Plant and Soil Sciences from the University of Delaware. He comes to ARS from the University of Maryland. He specializes in geospatial modeling at regional and national scales.
- **Dr. Tony Adesemoye** was hired as a Research Pathologist in the National Soil Dynamics Laboratory (Auburn, AL) to conduct research on Southeastern US Forage Improvement. Dr. Adesemoye will be supporting and improving forage production using plant growth promoting rhizobacteria (PGPR) technologies. Dr. Adesemoye came to ARS from Texas A&M University.
- **Dr. Aleksandr Kavetskiy** was hired as a research scientist in Engineering (Nuclear Physics) at the National Soil Dynamics Laboratory (Auburn, AL) to conduct research on soil carbon scanning technology. His prior position was as a post-doctoral fellow in the same laboratory.
- **Dr. Carrie Laboski** was hired as a Research Leader at the Pasture Systems & Watershed Management Research Unit (University Park PA). Dr. Laboski's research is focused on improving sustainability and resilience of agroecosystems through improved soil fertility and nutrient management practices. Before joining ARS, Dr. Laboski was a Professor and Extension Specialist at the University of Wisconsin-Madison.
- The Genetics and Sustainable Agriculture Research (Mississippi State, MS) welcomed the following new personnel: **Joshua Waldbieser** as a graduate student assistantship. Joshua Waldbieser is working on a MS degree in computer science at Mississippi State University. **Austin Cook** accepted a position as a Student Trainee. He is completing his MS degree this year under the direction of Dr. John Brooks.
- **Emily Myers** joined Southeast Watershed Research Unit (Tifton, GA) as a Student Trainee (Biological Science).

The following left the ranks of NP216 in 2022:

- **Dr. Thomas Sauer**, Research Leader/ Supervisory Soil Scientist retired from the National Laboratory for Agriculture and The Environment: Ames, IA Unit. He was known for his work on soil heat flux measurements. Dr. Sauer led a 20+ year agroforestry project in

NW Arkansas, was involved in leadership roles in the Soil Science Society of America and the International Union of Soil Sciences and was acting Laboratory Director for 2½ years.

- **Dr. Debra Peters** retired in 2022 from the Range Management Research Unit (Las Cruces, NM). She served her last several years as acting Chief Scientific Information Officer (CSIO) for ARS.
- Grassland Soil and Water Research Laboratory (Temple, TX) said farewell to two retiring Research Ecologists, **Dr. Wayne Polley and Dr. Phil Fay**.
- **Dr. Hal Collins** retired as a Research Soil Scientist from the Grassland Soil and Water Research Laboratory (Temple, TX).
- **Dr. Earl Vories**, a Research Agricultural Engineer in the Cropping Systems and Water Quality Research Unit (most of which is in Columbia, MO, but Dr. Vories primarily served at a worksite in Portageville, MO) retired from ARS in 2022. Dr. Vories is internationally recognized for his work to improve irrigation systems for humid and sub-humid climates, and for his contributions to precision, variable-rate irrigation.
- **Dan Arthur,** Ecoinformatics & IT Specialist at the Pasture Systems and Watershed Management Research Unit (University Park, PA) moved on from ARS in 2022 to a position with United States Geological Survey (USGS) in Colorado.
- **Dr. Jack Meisinger**, who had retired from ARS after a 45+ year career as a research scientist and was continuing to collaborate on a nitrate leaching experiment with his former colleagues at the Sustainable Agricultural Systems Laboratory (Beltsville, MD) passed away in November 2021. Dr. Meisinger was internationally known for his work with nitrogen dynamics in soils and cropping systems. He was a Fellow of the American Society of Agronomy and the Soil Science Society of America, as well as a recipient of the USDA Team Distinguished Service Award. John Joseph " Jack" Meisinger Obituary
- **Dr. John Read** passed away in 2022. He was a Research Agronomist/ Plant physiologist. He worked for the USDA for 31 years and contributed to the research community Agronomy. Dr. John Read was elected as 2021 Fellow of the American Society of Agronomy for his outstanding contributions to agronomy through education, national and international services, and research.
  Dr. John Read Obituary

The following scientists in NP 216 received prominent awards in 2022:

- **Dr. Sheri Spiegal** Range of the Management Research unit (Las Cruces, NM) won the 2022 Herbert L. Rothbart Outstanding Early Career Research Scientist award for collaborative, systems-level research on nutrient management and holistic agricultural indicator systems.

    - https://www.lascrucesbulletin.com/stories/nmsu-research-rangeland-management-specialist-receives-national-award,11393

- **Dr. Dexter Watts** of the Soil Dynamics Research unit (Auburn, AL) received the 2022 American Society of Agronomy Environmental Quality Research Award

The quality and impact of NP216 research was evidenced during FY2022 by the following:

- 163 refereed journal articles and eight book chapters published.
- 31 new incoming agreements with collaborators and 58 outgoing agreements.
- 1 invention disclosure submitted; and
- 105 students and postdoctoral research associates training with ARS.

Selected Research Accomplishments for FY2022

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

Long term application of poultry litter and cover cropping benefits farmers in the U.S. Southeast. ARS researchers in Mississippi State, Mississippi, established several field studies to evaluate the effects of poultry litter, pelleted biosolids, biochar, and cover crop on soybean yield, soil characteristics, plant water availability in soil, and rainwater use efficiency. In one 5-year study, they evaluated repeated poultry litter applications to soil under a corn-cotton-soybean rotation and found the application significantly improved a range of important soil characteristics in comparison to more traditional inorganic fertilizer treatments. The applications led to soils that were less compacted and could hold significantly more water because the litter allowed rainwater to soak into the ground more quickly. Soybean yields also increased 8 to 11% in the years following poultry litter amendments compared with yields from fields treated with synthetic fertilizers. In parallel studies, this team evaluated cover crop impacts in 5-year studies and noted additional positive outcomes, including increases in soil organic matter and increased levels of rainwater stored in soils. Cover crops are still relatively new to cropping systems in the region, and both the NRCS and farmers in the region have shown interest in these practices and outcomes. The findings demonstrate the value of poultry litter as an additional income stream for poultry farmers and for increasing yields and soil quality, and the benefits of cover cropping. It is expected that these findings will further expand the adoption of both and will lead to system-level agronomic benefits.

A powerful national soil health interpretation and recommendation tool. Adoption of soil health practices has been hampered in part by the lack of a scientifically robust and user-friendly interpretation tool. An ARS researcher in Columbia, Missouri, led a team of scientists from multiple other institutions in development of a framework called the Soil Health Assessment Protocol and Evaluation (SHAPE). This tool accounts for inherent site conditions, such as soil type and climate, and provides a soil health score for up to four soil health indicators at any location across the continental United States. Version 1.0 of SHAPE is complete and is publicly available online via GitHub and as a Shiny App. This research benefits producers and scientists by providing an improved soil health interpretation tool to monitor changes in soil health, provide management recommendations to landowners, and inform soil health programming efforts.

Economically marginal land can be suited for growing switchgrass. Producing bioenergy crops can increase farm income and provide environmental benefits, but clear criteria are needed to identify land that can be more profitable than growing existing crops. Researchers at the University of Illinois in collaboration with an ARS scientist in Mandan, North Dakota, used historical yields for an Illinois agricultural field and a Soil Productivity Index (SPI) approach across Illinois to identify land that is economically marginal for annual crop production, and that may be thus suited for growing switchgrass. The SPI is a tool that has been developed that enables the assessment of the yield potential of Illinois soils. In this indexing tool, optimal agricultural lands are considered those having SPIs ranging from 100 to 147. This optimal agricultural land is further subdivided into three classes, with Class A having an SPI of greater than 133, Class B having an SPI ranging from 117 to 132 and class C lands ranging from 100 to 116. Lands with SPIs of less than 100 are considered non-prime agricultural locations. Using these approaches, the study found when switchgrass could be more economical than soybeans or corn in some soils and where the value of switchgrass was high. A key study in Illinois, showed that the switchgrass offered high value against soybean production when switchgrass was valued at or over $80 per ton. For corn, and depending on location, switchgrass was an attractive opportunity when switchgrass pricing was at $60 per ton or more. Across Illinois, if switchgrass was valued at $80 per ton or greater, all Illinois land with a SPI less than 100 is profitable for switchgrass - and 95 percent of land in the SPI class C (100 to 116 SPI) is profitable under switchgrass. Switchgrass, however, may not be profitable relative to corn grown in the SPI class A and only 7 percent of Class B. These results are useful to crop producers, policy makers, and bioenergy businesses in identifying areas where switchgrass production could be economically viable. Further opportunities for switchgrass considerations may expand if in the future, the ecosystem service benefits are evaluated.

Organic rotations provide more efficient water use in the spring and fall. More efficient use of plant-available water in the spring and fall may result from the plant biodiversity in organic systems compared with a conventional corn-soybean (C-S) system. If wet periods occur within the growing season, greater plant capture of water in the spring may reduce in-season surface runoff and leaching. ARS researchers in Ames, Iowa, and collaborators showed that an organic forage system took up more plant-available water in the spring and fall than a conventional C-S rotation. A 4-year rotation (corn, soybean, oat with first-year alfalfa, second year alfalfa) was intermediate in water use. The leaf area index for the corn and soybean (a measurement of crop growth) did not show a consistent difference between conventional and organic corn or soybean. In the wet year of 2018, weed pressure hindered organic soybean growth. Data collected indicated that there was a positive relationship between crop uptake of plant-available water and grain yield for both corn and soybean. Having crops on the land for a longer portion of the growing season could be beneficial in drying the soil during wet springs. Overall, this study demonstrated that organic agricultural systems have positive benefits for timing of water use. This information is important for organic farmers and their advisors.

Potential carbon mineralization is an effective soil health indicator for dryland cropping systems. Much of the agricultural soil throughout the world has been degraded by intensive tillage and topsoil erosion. As efforts increase to regenerate healthy, productive soil in many crop production areas, assays are needed to allow managers to monitor changes in chemical, physical and biological soil quality. Labile carbon fractions that change rapidly within a growing season are promising soil health indicators, but they must be correlated with soil properties and crop yields to be suitable metrics. ARS researchers in Sidney, Montana, and Soil Health Institute researchers evaluated the relationships among soil carbon fractions and 62 soil properties and mean crop yields in two long-term (14 and 36 years) experiments in dryland farming systems in eastern Montana. They reported that potential carbon mineralization, which indicates soil microbial activity, was better related to soil properties and crop yields than other soil carbon fractions. Producers can use potential carbon mineralization as a promising indicator to measure soil health in dryland cropping systems in the semiarid climatic conditions.

Component 2. Increasing Efficiencies for Agroecosystem Sustainability

Enhancing drought resilience via collaboration and partnership. Water scarcity has long been the paramount challenge in the U.S. Southwest and drought intensity and duration are expected to increase in the region. Recent exceptional drought (the highest classification in the U.S. Drought Monitor) has impacted wildfire potential, agricultural production, water management, the economy, and human well-being. Until recently, the region lacked a way to succinctly document and communicate the novel drought experiences and responses among service providers, federal and state officials, scientists, and stakeholders. ARS scientists in Las Cruces, New Mexico, the USDA Southwest Climate Hub, the National Integrated Drought Information System (NIDIS), and the National Drought Mitigation Center (NDMC) initiated the Southwest Drought Learning Network (DLN) to convene and learn from people studying and experiencing drought. In fiscal year 2022, the DLN had more than 115 members and formed five teams based on the most relevant needs of the region at that time. The DLN's reach has been broadened through partnership and collaboration, leading to expanded monitoring and impact reporting, nine drought briefings (reaching at least 2,700 listeners), and articles to document drought response and efficacy. The DLN's indigenous collaboration team co-hosted an in-person tribal drought summit, and natural resource managers from more than 15 pueblos attended and expanded precipitation monitoring on tribal lands via installment of more than 50 myRAINge and CoCoRaHS gauges. The DLN provides framework for collaboration and links scientists with resource managers to develop scientific solutions for one of the most challenging weather and climate impacts in the region.

Biocrusts stimulate subsurface nitrogen cycling activity. Biological soil crusts (biocrusts) occur naturally across many ecosystems worldwide, including deserts, polar regions, and agricultural systems. Biocrusts form in the top millimeters of soils and are often comprised of a variety of microorganisms, including diverse cyanobacteria, moss, algae, fungi, and archaea. ARS researchers in Pendleton, Oregon, and University of Florida collaborators evaluated the effects of native agricultural biocrusts on the soil moisture, nitrogen-cycling capacity, and microbiome composition in the upper root zone of a sandy soil citrus orchard in Florida. Compared to bare soil, the soil beneath biocrusts had increased soil moisture during the dry season, greater soil nitrogen during citrus growth stages of high nutrient demand, and higher microbial community activity and relative abundance of microbes involved in nitrogen cycling. This information can guide producers to conserve naturally forming biocrusts as tools to increase soil health and influence nitrogen availability in crop production.

Cover crop nitrogen calculator for adaptive nitrogen management. Farmers and ag professionals need decision support tools that estimate nitrogen availability from cover crops to inform their nitrogen fertilizer application rates. ARS scientists in Beltsville, Maryland, along with scientists from the University of Georgia and North Carolina State University, used data from a large on-farm research network (the Precision Sustainable Agriculture network) to improve a predictive model and redesign the user interface for the Cover Crop Nitrogen Calculator (CC-NCALC). The improved CC-NCALC estimates nitrogen availability from cover crop residues based on residue environment (i.e., residue moisture and temperature) and nitrogen limitations of the residues and soil. It uniquely considers the fractional plant residue mass in contact with the underlying soil. The calculator offers site-specific residue and adaptive nitrogen management information to farmers, ag professionals, researchers, and policymakers and is an educational tool for teaching university students.

Advancing innovative and improved models to best manage crops and address climate change in agriculture. It is essential to understand the mechanisms and conditions that drive agricultural land suitability. ARS researchers in Beltsville, Maryland use modeling to project and manage crops and agroecosystems for optimal, climate-adapted current and future productivity and sustainability. Improved models can more accurately simulate the processes that contribute to soil health and agricultural sustainability – and that concurrently are important to optimize crop management. The team added a series of enhancements to the USDA-ARS model 2DSOIL that improved simulation of soil organic matter dynamics, gas transport equations for the diffusion of carbon into and out of the atmosphere, simulation of carbon and nitrogen dynamics of manures and buried residue, and a tillage module to allow mixing of the surface soil along with surface deformation. The improvements have been integrated with other crop models, including USDA-ARS MAIZSIM model, and are powerful for exploring consequences of farm management choices on soil health and on GHG dynamics and carbon sequestration. Soil health is integrally connected to land suitability, and changing climate threatens to change land suitability and reduce yield potential. The team investigated application of the AI-driven Maxent model to predict crop suitability and developed relevant and novel methods of evaluating its predictive ability. Maxent performance and outcomes were compared to more standard modeling approaches to predict land suitability for corn production in the contiguous U.S. under current bioclimatic conditions. Maxent was effective in modeling areas in which land was suitable for corn, even where the current cropping practice was not corn production. Maxent also proved to be an effective method for predicting corn yield using current land cover and climate as inputs. By altering climatic inputs, the model can likely model future land suitability and the climatic impacts on yield potential, revealing where future climate adaptation and mitigation strategies can be most effective. Together, these two powerful modeling innovations assist the agricultural community in addressing and implementing suitable cropping systems that optimize productivity, sustainability and soil health.

Component 3. Reaching Agroecosystem Potential

Regional freeze date trend tool for important cropping decisions. Specialty and row crop production are being severely affected by changing freeze dates and growing season length. Various measures of climate changes exist regionally and nationally, including temperature, precipitation, and humidity data, but there were no measures for local updates about changes in freeze dates (last spring and first fall). Previous maps from the 4th National Climate Assessment showed only season-length changes by multi-state regions. ARS staff in Ames, Iowa, cooperated with the USDA Midwest Climate Hub and the Midwest Regional Climate Center at Purdue University and created a publicly available county-level freeze/frost date tool using gridded temperature data since 1950 to calculate and display trends in first fall and last spring freeze dates and growing season length. Specialty and row crop producers can use this information to improve crop management decisions in a changing climate and minimize crop losses and damage related to unseasonal frost events.

Winter cover crops can improve summer crop yields even after harvest. Legumes planted as winter cover crops in the U.S. South can improve soil health and enhance crops the following summer by capturing nitrogen from the air. Winter covers are often tilled under or left in the field and rolled, but they could be harvested for forage. ARS researchers in Tifton, Georgia, conducted a 5-year study to compare biomass yields of five different legumes or rye, along with fallow checks. The covers were either harvested or rolled and were followed with high-biomass sorghum or cotton. Narrow-leaf lupin was the highest-yielding winter cover. Lupin, vetch, and winter pea covers had positive effects on summer biomass sorghum yields, and cotton lint yields were highest after lupin and vetch. Harvesting the covers reduced sorghum yields following some covers but not following lupin or vetch. Cotton yields were not affected by harvesting versus rolling of any winter covers. The study suggests that growers could harvest lupin and vetch for animal feed and still improve summer row crop yields, thus increasing overall farm income and improving soil health.