National Program 216- Sustainable Agricultural Systems Research
National Program Annual Report for FY2019

Introduction

Fiscal year 2019 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 National Program 216 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

The 216 National Program 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.

2019 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 2019, NP216 scientists participated in research collaborations with scientists from Argentina, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Honduras, India, Italy, Japan, Kazakhstan, Mexico, Mongolia, Mozambique, Nigeria, Northern Ireland, Norway, Peru, South Korea, Spain, Switzerland, Taiwan, Turkey, United Kingdom, and Uruguay.

During FY2019, 101 full-time scientists working at 23 research units across the U.S. actively engaged in 25 ARS-led and 140 collaborative research projects. Program funding was $55M.

Personnel news for NP 216

New additions to the NP216 team in 2019 are:

- **Dr. James Kim** joined the Plant Physiology & Genetics Research Unit in Maricopa, AZ as a Research Agricultural Engineer to provide support for the high-throughput phenotyping (HTP) program. James got his PhD in Agricultural Engineering from the University of Illinois at Urbana-Champaign, and is an expert in the development and application of HTP for crop improvement and management. He has prior experience working in the public sector, including Purdue University and the USDA-ARS, as well as the private sector, including Monsanto and John Deere.
- **Dr. Sheri Spiegal** was hired as a Research Animal Scientist at the Range Management Research Unit in Las Cruces, NM to investigate heritage beef breeds and ecosystem services in beef production systems. Sheri got her PhD in Environmental Science, Policy, and Management and her MS in Range Management from the University of California, Berkeley. She did a post-doctoral fellowship with the USDA-ARS in Las Cruces. Sheri uses ecological

site description and livestock tracking to design management strategies that conserve both natural resources and input costs for ranchers.

- **Dr. Ripley Tisdale** joined the Plant Science Research Unit in Raleigh NC as a new scientist studying crop-root and soil microbial interactions under environmental stresses. The unit also welcomed visiting scholars **Katiuca Sueko Tanaka** of Sao Paulo State University in Botucatu, Sao Paulo, Brazil, and **Luanda Torquato Feba** from Universidade do Oeste Paulista (UNOESTE) in Presidente Prudente, Sao Paulo, Brazil. Both are studying soil aggregation in long-term crop experiments.
- **Dr. Rachael Christensen** joined the Northern Great Plains Research Laboratory in Mandan ND as a Research Animal Scientist. Her efforts will lead to the development of land and livestock management practices that will enhance agricultural sustainability. She received her B.S. in genetics and cellular physiology/ animal science from Brigham Young University-Provo and her M.S. and PhD in dairy management and ruminant nutrition and physiology, respectively, from Utah State University.
- **Dr. Andrea Clemensen** also joined the Northern Great Plains Research Laboratory in Mandan ND as a postdoctoral research associate. Andrea is working with Dr. John Hendrickson on the Healthy Soil – Healthy Food – Healthy People project in collaboration with the ARS labs in Fargo, ND and Grand Forks, ND. She received her Ph.D. in Ecology from Utah State University. Andrea's research at the NGPRL is part of the Sustainable Agricultural Systems for the Northern Great Plains Research Project. This project builds on continued research at the NGPRL assessing how management impacts ecosystem services in ever-changing environments. The project works in collaboration with other ARS locations, and also includes the National Ecological Observatory Network (NEON) and the Long Term Agroecosystem Research (LTAR) network, with overlying objectives to improve agricultural ecosystems while enriching crop nutrition.
- The Range Management Research Unit in Las Cruces, NM had two new postdoctoral research associates in 2019: **Dr. Shawn Taylor** from University of Florida, Gainesville, whose focus is on plant phenology for the LTAR network, and **Dr. John Humphries** from Florida State University, whose focus is on vesicular stomatitis.
- **Dr. Matthew Herritt** was hired as postdoctoral research associate by the Plant Physiology & Genetics Research Unit in Maricopa, AZ. Matt got his PhD in from the University of Missouri, Columbia. Matt is an expert in the physiological and biochemical responses of plants to stress (particularly in regards to photosynthesis), and much of his work in Maricopa has focused on studying radiant use efficiency in crop plants and development and utilization of high-throughput phenotyping technologies for these purposes.

The following scientist left the ranks of NP216 in 2019:

- **Dr. Jeffrey White,** Research Plant Physiologist with the Plant Physiology & Genetics Research Unit, Maricopa, AZ retired on Dec. 31st, 2018. He made significant contributions to the areas of crop simulation modeling and development of high-throughput phenotyping technologies for monitoring crop performance in the field.

The following scientists in NP 216 received prominent awards in 2019:

- **Dr. Ken Sudduth** of the Cropping Systems and Water Quality Research in Columbia MO was awarded the American Society of Agricultural and Biological Engineers John Deere Gold Medal for "Distinguished Achievement in the Application of Science and Art to the Soil," and ARS Midwest Area Senior Research Scientist of the Year in 2019.
- **Dr. David Toledo of** the Northern Great Plains Research Laboratory in Mandan, ND was elected to the Board of Directors of the Society for Range Management. His primary responsibilities are in developing integrated grazingland assessment for use in management and conservation planning. His previous research includes working at the USDA-ARS Jornada Experimental Range in Las Cruces, NM working on the development and application of indicators for monitoring soil and vegetation attributes and assessment of rangeland health.
- **Dr. Brandon Bestelmeyer**, Research Leader of the Range Management Research Unit (RMRU), Las Cruces NM, was presented an "Honored Worker of Agriculture" award from the Minister of Food, Agriculture, and Light Industry of Mongolia. This honor recognizes 10 years of contributions by RMRU staff in developing an integrated rangeland classification, monitoring, and management system in Mongolia.
- **Dr. Eric Brennan** of the Crop Improvement and Protection Research Unit in Salinas, CA received the *Outstanding Cross-Commodity Publication Award* from the American Society of Horticultural Science, for his paper, "The Slide Hammer Seeder: A Novel Tool for Planting Small Seeds."
- **The National Peanut Research Laboratory**, Dawson GA, was awarded the 2020 Georgia Peanut Research and Education Award by the Georgia Agricultural Commodity Commission for Peanuts.

The quality and impact of NP216 research was evidenced during FY2019 by the following:

- 166 refereed journal articles published;
- 4 new material transfer agreements with collaborators;
- 2 new patent applications filed and 2 new invention disclosures submitted; and
- 136 students and postdocs training with ARS.

Selected Research Accomplishments for FY2019

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

U.S. beef cattle production has a relatively low environmental footprint. The U.S. beef industry is a major contributor to the national and global food system and economy. Increasing productivity in an environmentally, economically, and socially sustainable manner is of concern to both producers and consumers. Our cattle production systems are very complex, with many components and interactions, so quantifying and measuring sustainability is challenging. Through a comprehensive national assessment, ARS scientists in University Park, Pennsylvania, in collaboration with the National Cattlemen’s Beef Association, found beef cattle production emitted 3.3 percent of the Nation’s greenhouse gas emissions, produced 15 percent of reactive nitrogen losses, used 0.7 percent of fossil energy, and consumed 5.8 percent of its fresh water. When these figures are expressed per unit of meat produced, they compare very favorably with global averages. These data provide a baseline for comparison with future assessments and the evaluation of potential benefits of mitigation strategies.

Cow-calf pairs grazing in pasture (top) and beef cattle in a feed lot (bottom)

Quantifying the sustainability of beef. The long-term sustainability of beef has become a national and international concern. Although many reports are made on the negative environmental and social impacts of beef, little comprehensive, science-based data exist to support these claims. ARS scientists at University Park, Pennsylvania in collaboration with scientists at the National Cattlemen's Beef Association and BASF Corporation conducted a full life cycle assessment (LCA) of U.S. beef using data from a typical cattle production operation and primary packing, processing, retail and restaurant operations along with consumer and waste handling information. This LCA, which includes 10 measures of impact, is the first of its kind for beef and has been third party verified in accordance with international standards. The analysis provides baseline information for comparing beef production systems and measuring the benefits of future improvements in sustainability.

Less nitrogen fertilizer needed for sugarbeet following soybean. Synthetic nitrogen fertilizer is one of the largest inputs in sugarbeet-based irrigated cropping systems of the northern Great Plains. Sugarbeet is usually grown following a small grain. If an annual legume precedes sugarbeet, it provides biologically-fixed nitrogen which may alter seasonal nitrogen availability patterns. ARS researchers at Sidney, Montana evaluated the performance of sugarbeet grown following soybean compared to sugarbeet following barley. Where soybean preceded sugarbeet, the target nitrogen fertilizer rate was reduced by 25 to 30 kilograms per hectare due to nitrogen provided by soybean residue. Sucrose yield was greater following soybean than following barley two of seven years and was similar in the other five years. Results suggest that soil and plant organic nitrogen are released more evenly throughout the growing season following soybean than following barley. It was concluded that growing sugarbeet following soybean reduces the amount of nitrogen fertilizer required for sugarbeet without negatively affecting yield. Moreover, soybean requires no synthetic nitrogen fertilizer because it is able to meet its own nitrogen needs through biological nitrogen-fixation. When both soybean and sugarbeet production years are considered, nitrogen fertilizer costs are about $275 per hectare lower compared to the rotation with barley in place of soybean. Reducing the use of nitrogen fertilizer benefits growers' bottom line and reduces environmental impact resulting from the production and use of nitrogen fertilizers.

Soil-test biological activity is an effective predictor of N fertilizer response in pastures. Fertilization of perennial pastures with nitrogen may not always be cost-effective, due primarily to stored nitrogen in soil organic matter that can be released for plant uptake. ARS scientists in Raleigh, North Carolina, with collaborators from North Carolina State University evaluated tall fescue yield response to fall-stockpiled nitrogen application in a series of 55 field trials throughout Georgia, North Carolina, Virginia, and West Virginia. Yield response was either nil, modest, or high among various sites. Those sites predominantly with high soil-test biological activity and associated high nitrogen mineralization potential led to no yield response. Those sites with low soil-test biological activity and low nitrogen mineralization had high yield response. Soil-test biological activity can be used to indicate the need to add fertilizer to pasture, so that producers can fine-tune nitrogen applications for greater production and profit, as well as to limit nitrogen losses to the environment. (6070-11000-010-00D; 216 1B)

Cover crop residue improves weed control in cotton. Due to unprecedented cotton yield loss due to herbicide-resistant weeds, there is an urgent need for integrated weed management strategies. The critical period for weed control (CPWC) is the time interval in crop growth when a weed-free state must be maintained to prevent substantial (=5%) yield loss. In a study by ARS scientists in Auburn, Alabama, evaluating three systems, rye biomass suppressed early season weed biomass and delayed the start of the CPWC. The presence of a high residue rye cover crop delayed the critical timing for weed removal (CTWR) approximately 8 days compared to fallow treatments. Thus, winter fallow should be avoided to minimize cotton yield loss in conservation systems. Due to this research, Extension recommendations for integrated weed management are being revised to reflect weed suppressive attributes high-residue cover crops provide when establishing weed management strategies in conservation tillage cotton. Producers and crop advisors are more likely to utilize high residue cover crops if they understand the benefits and challenges conservation systems provide.

Integrated weed management system for watermelon. Specialty crops historically have been grown in high intensity conventional tillage systems. High residue cover crop systems integrated with traditional vegetable production practices likely offer solutions to some weed management challenges in conservation tillage specialty crop systems. An ARS scientist in Auburn, Alabama, grew watermelon while integrating minimal herbicide input, a high residue cover crop and polyethylene mulch, compared to a traditional conventional tillage polyethylene mulch system. Results reveal the integrated system provided successful alternative weed control practices compared to traditional systems. As a result of this research, Extension, USDA-NRCS, and growers increasingly recommend and adopt integrated weed management recommendations that control weeds, decrease economic risk, and protect the environment.

Adoption of no-till and cover crops shifts carbon balance. Conversion of a conventionally tilled field to a cover crop no-till management system revealed that this change improves the carbon balance with minimal impact on the water balance. Previous research has shown that conventionally tilled corn-soybean fields had a negative carbon balance and reducing tillage and adding a cover crop shifted the carbon balance to a positive net ecosystem productivity. The primary factor responsible for this change was the reduction in soil disturbance. With intensive grid soil sampling in this field, ARS researchers at Ames, Iowa, showed that after two years of cover crops and no-till, there was a doubling of the microbial biomass in the upper 15cm of the soil profile. Understanding the coupling of carbon and water in agricultural systems provides a framework for quantifying how changes in agricultural management will have a positive or negative effect. This is providing producers with information on soil management practices that will enhance their soil to increase productivity across fields.

Diversified no-till crop rotations improve dryland farming systems. Traditional tillage once during the 2-year rotation causes soil compaction and N loss to the environment. ARS scientists in Sidney, Montana evaluated the effect of crops with varying rooting characteristics on soil compaction. No-till cropping systems with durum wheat rotated with camelina, carinata, a cover crop mix, or fallow were evaluated on a field with a history of tillage-induced soil compaction. There was no amelioration of compaction after one 2-year cropping cycle, but compaction was reduced by 28% after two cycles, regardless of the rooting characteristics of the rotation crops. In a separate experiment, ARS scientists in Sidney, Montana found that a no-till barley-pea cropping system, where only modest amounts of nitrogen fertilizer were applied, increased crop nitrogen removal, enhanced soil nitrogen storage, and decreased nitrogen loss to the environment, compared to a tilled fallow-barley system. This low nitrogen-input system resulted in a nitrogen balance close to zero, which is a notable improvement compared to the negative nitrogen balance observed with the tilled-fallow system. Producers can enhance dryland crop production while ameliorating soil compaction and improving nitrogen balances by transitioning to a no-till system with diversified continuous cropping instead of fallow.

Pea germplasm identified with improved resistance to Fusarium root rot. *Fusarium avenaceum* is a fungus that causes severe root rot disease of pea throughout the major production regions of the U.S., including Idaho, Montana, North Dakota, and Washington. Currently there are no fungicides available against this disease and genetic resistance is the most effective and sustainable approach for disease management. ARS researchers in Prosser, Washington, evaluated 444 pea lines from the Pisum Collection and 28 popular commercial pea varieties for Fusarium resistance using a highly reliable greenhouse screening method. A total of 34 lines were identified that had greater levels of disease resistance than the other tested lines. These lines are being used by breeders to develop new pea varieties that have high levels of disease resistance coupled with important field and nutritional quality traits.

Criollo cattle are better adapted to semiarid rangelands than traditional cattle breeds. New world Raramuri Criollo cattle have undergone approximately 500 years of natural selection and adaptation to harsh rangeland conditions. ARS scientists in Las Cruces, New Mexico found that nursing cow-calf pairs and dry Criollo cows travelled similar distances per day, moved at similar speeds, and did not differ in time spent grazing, resting, or traveling each day. Area explored per day by a calf and its mother were similar and cow-calf contact events occurred throughout the entire area grazed by the dams. This biotype exhibited a strong follower behavior, suggesting Raramuri Criollo cows are less constrained by the presence of a calf than conventional breeds of rangeland cattle. Identifying cattle types whose natural behaviors are suited to the forage resources in extensive semiarid ecosystems will benefit ranchers by allowing optimal use of available forage.

Optimizing nitrogen fertilization may be the best way to produce nutrient-rich corn grain. Enriching the corn grain with mineral elements, iron and zinc in particular, would have human and animal nutrition implications. Currently, the most accepted approach to enriching grains of corn and other cereal crops is through biofortification by genetic manipulation or application of the mineral elements directly on the plant. Poultry litter use as a fertilizer in crops such as cotton and corn is known to enrich the soil and plant parts with phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), and other mineral elements. ARS researchers at Mississippi State, Mississippi, investigated whether fertilizing corn with poultry litter increases the levels of mineral elements in the grain beyond that possible with conventional fertilization with synthetic fertilizers. The results showed that elevating the level of N (and therefore protein) in the corn grain by supplying optimal N fertilization, regardless of the source, was key to enriching the grain with mineral elements including P, K, Mg, Zn, Fe, and manganese (Mn). The levels of these elements in the corn grain increased in direct proportion to the level of protein or N in the grain regardless of whether these elements were added to the soil. Grain protein in turn was a direct function of the amount of N the corn plant received from poultry litter or synthetic sources. The results suggest that optimal N fertilization may be the best approach to produce not only optimal corn grain yield but also nutritious grain. The results have direct implications for corn produced for food and feed, demonstrating that precision nutrient management in the field can impact the nutritional qualities of the grain. This could lead to increased livestock feeding efficiencies, reduced loss of nutrients to the environment, and improved nutrient profiles for corn-based food products.

Component 2. Increasing Efficiencies for Agroecosystem Sustainability

Corn and cattle profitability improved by grazing corn crop residue. Grazing on corn residue by beef cattle provides a simple and economical practice for integrating crops and livestock in the central United States. However, the overall economic value of this practice was unknown. ARS scientists in Lincoln, Nebraska, in collaboration with university colleagues determined that this type of grazing annually returned $95 million to crop producers in Kansas, Nebraska, North

Dakota, and South Dakota. The annual gross value for grazing corn residue for cattle producers was $191 million in those States. Although challenges exist to expand corn residue grazing, opportunities also exist to increase utilization of this cost-efficient winter forage alternative.

Cattle grazing corn crop residue in Nebraska

Organic agriculture's risk of phosphorus pollution is mitigated with legume cover crops. Manure is a potent source of both nitrogen and phosphorus. Organic systems often use manure as a nitrogen source, which can lead to excessive phosphorus application and runoff into waterways. Legume cover crops supply enough nitrogen to reduce poultry litter application requirements in organic corn production systems. enabling farmers to mitigate phosphorus pollution. In a 2-year study at three organic sites in Maryland, ARS scientists found that poultry litter application can be reduced by half and still achieve the same corn grain yield when used in conjunction with a legume cover crop. These results will be of interest to farmers, environmentalists, policy experts, and others concerned with the health of the Chesapeake Bay and other estuaries impacted by agricultural losses of nitrogen and phosphorus.

Building climate-resilient landscapes and communities in the Southwest. Weather and climate impacts on Southwestern U.S. ecosystems and communities include weather-related crop loss, large interannual and spatial variability in precipitation and rangeland production, wildfire, and extreme drought. As members of the USDA Southwest Climate Hub (SW Climate Hub), ARS scientists in Las Cruces, New Mexico completed the launch of two online decision support tools (the AgRisk Viewer and the Climate Smart Restoration Tool) and contributed to drought vulnerability assessment projects linked to ecological sites. The SW Climate Hub team also coauthored the 4th National Climate Assessment. Collectively, these efforts will assist Southwestern farmers, ranchers, foresters, and other land managers in strategically adapting to the impacts of extreme weather and climate change.

Pelletized poultry litter (PPL) provides residual nitrogen and increased moisture retention after applications cease. Sustainable agriculture is reliant upon keeping soil healthy enough to maintain water holding capacity and adequate nutrients for crop productivity. Sub-surface application of pelletized poultry litter is a relatively new and effective application method since it delivers nutrients in direct proximity of the root zone, while also maintaining a residual soil nutrient level which can be exploited in subsequent years. ARS researchers at Mississippi State, Mississippi, conducted a multi-year study to determine the impact of pelletized poultry litter on cotton lint yield, soil nutrients, and soil physical and hydraulic properties. Cotton leaf qualities were increased by applying urea to plots with residual poultry litter during boll-filling stages. Plots with residual pelletized poultry litter and applied urea increased lint yield by as much as 10% compared with standard fertilization. Annual pelletized poultry litter application also increased soil aggregate stability, plant available water, field capacity, saturated hydraulic conductivity, and infiltration. Pelletized poultry litter offers a sustainable practice for increasing cotton yield in the humid Southeastern United States.

Relay-cropping with soybean and oilseed maintains profitability while improving winter soil cover. Growing crops to maintain cover over the winter could provide environmental benefits, but it is challenging in Northern climates with added costs of winter crop establishment and potential negative crop yield impacts. ARS scientists in Morris, Minnesota and Mandan, North Dakota, along with scientists from the University of Minnesota and University of Wyoming, evaluated yields and economics of four winter cover options compared to two winter fallow treatments in a spring wheat-soybean rotation at three sites in Minnesota. The winter cover options included camelina and pennycress that were relay-cropped with soybean and harvested over the soybean canopy, and traditional cover crops winter rye and forage radish that were not harvested. Total seed yields for the relay-crop options were similar to and sometimes exceeded those of soybean grown alone in the traditional winter fallow treatments. Net incomes for the relay-crop options were also similar to soybean grown alone, so these may be the most economically favorable winter cover options for producers. This information is useful to producers in selecting winter cover practices.

Innovative method for cover crop termination using engine exhaust heat. Heat has been used in agriculture in the form of an open flame to control weeds. However, these systems require an additional fuel source. Researchers in Auburn, Alabama, focused on utilizing wasted exhaust heat to terminate cover crops and control weeds in conservation systems. To evaluate this concept at a small farm scale, a mechanical pusher using exhaust heat from the internal combustion gasoline engine with supplemental heat from heater strips was developed to terminate cover crops. The prototype was developed for a walk-behind tractor powered by a single cylinder gasoline engine. Heat to damage plant tissue was directed from the exhaust manifold to a rectangular perforated delivery steel tube that was in continuous contact with the cover crop that had been flattened by the pusher. In addition, a generator powered by the tractor's Power Take-Off (PTO) provided electrical energy for three parallel supplemental heater strips. Results demonstrated that using exhaust heat (otherwise lost to the environment) is an economical means to terminate cover crops.

The range of Kudzu invasion and impact will expand northward with climate change. Kudzu, an invasive species, has been reported to infest nearly 8M acres now, much of that in commercial forest production. Treatment costs commonly exceed the economic value of the timber harvest Kudzu is a carrier of Asian soybean rust, a fungus that can damage soybeans. Kudzu also is known to increase emissions of greenhouse gases such as nitrous oxide that further exacerbate climate change. To determine the role of rising temperatures on kudzu distribution, ARS scientists in Beltsville, MD, in conjunction with University partners looked at different populations of kudzu in relation to minimal freezing temperatures. The data indicate that kudzu has increased potential to migrate northward as temperatures rise, and that it has not reached its biological northward limit. Any expansion of the range of kudzu has potentially devastating consequences and this research provides new information that may help in identifying new areas at risk of kudzu invasion and associated negative impacts. Identifying areas most at risk of Kudzu invasion helps us develop targeted management to minimize damage.

Fertilizer nitrogen optimizes bioenergy feedstock production and environmental quality in semi-arid environments. Renewable bioenergy feedstocks offset the demand for conventional petroleum-based energy resources. Switchgrass is a warm-season perennial grass that has been utilized for lignocellulosic ethanol production. Beginning in 2009, ARS researchers at Sidney, Montana evaluated this bioenergy feedstock crop for its production potential in the semi-arid northern Great Plains, including the impact of nitrogen fertilizer application on biomass production and on environmental quality. Switchgrass biomass production ranged from 1.8 to 12.3 Mg per ha. Application of nitrogen fertilizer at a rate of 28 kg per ha increased biomass in most years. Response to higher nitrogen application rates was inconsistent due to variable rainfall. Biomass from fertilized switchgrass averaged 6.5 Mg per ha compared to 4.4 Mg per ha for the unfertilized control. Soil tests indicated that nitrogen fertilizer application above 28 kg per ha greatly increased the potential of nitrogen being lost to the atmosphere or ground water thus negatively impacting environmental quality in semi-arid environments. This research provides critical agronomic information that will enhance the capacity of the U.S. to produce alternative fuels with minimal environmental impact.

Strategy to diminish groundwater depletion. Groundwater in the Mississippi Delta has declined to an alarming level due to irrigation, threatening irrigated agriculture sustainability. ARS scientists at Mississippi State, Mississippi, investigated alternative water resources which could be used to replace groundwater for irrigation. Rainwater deficit from the past 120 years of weather records and irrigation demand of cotton, corn and soybean were determined. The coupled Soil and Water Assessment Tool–Modular Groundwater Flow model (SWAT–MODFLOW) was used to estimate weekly amounts of surface water available in ponds and streams. It was determined that weekly surface water resources are sufficient for major crop irrigation demand. These studies demonstrate that gains can be made on sustainable use of groundwater resources by a new approach to irrigation management that makes conjunctive use of surface water and groundwater in the Mississippi Delta.

A low-cost imaging sensor for crop temperature measurement. Quantifying spatial and temporal variability in plant stress is important for precision agriculture applications, including variable rate irrigation. A common approach is measuring crop canopy temperature measurement using infrared sensors, but current methods have limitations, including cost and reduced accuracy due to an inability to discriminate canopy from soil. ARS scientists at Columbia, Missouri, and colleagues from the University of Missouri developed a low-cost infrared imaging system that could discriminate sunlit crop areas from shadows and background. The system was successfully calibrated to measure temperature, and was able to discriminate plant from non-plant areas in field-collected images. The system will be of use to researchers and instrumentation developers interested in inexpensive ways to improve crop canopy temperature measurements.

Novel planter developed for small-seeded plants. Precision seeding of herbs, vegetables and other species with extremely small seeds that are the size of salt grains can be difficult with standard planters. Small seeds are often pelleted in order to plant them with precision, but this process is expensive. An ARS researcher at Salinas, California, developed a simple planter, called the Slide Hammer Seeder, for precision, hand seeding of unpelleted (raw), small-seeded species. The planter works well for seeding a variety of small-seeded herbs and vegetables and has been used to inter-seed sweet alyssum plants in vegetable crops. Sweet alyssum helps to control pest aphids on many vegetable crops and this novel seeder will help farmers do this more efficiently.

Component 3. Achieving Agroecosystem Potential

Carbon can be removed from the atmosphere and stored in soil by intercropping bioenergy crops with trees. Perennial herbaceous crops such as switchgrass are important sources of cellulosic biomass for the developing bioenergy industry. Assessments of how much carbon will be lost or sequestered into soil and the turnover rates of that carbon are needed to assist producers and policymakers who need to determine the long-term sustainability of biomass production. The natural 13C abundance of soils was used to calculate the quantity and turnover of C4-C in a switchgrass/poplar intercropping system. After 4 years of cropping, soil organic carbon increased 16 percent in the 0- to 15-cm depth. On average, 10 percent of soil organic carbon in that depth was derived from switchgrass. The results show that intercropping switchgrass with hybrid poplar gives forest plantation landowners greater economic returns from biofuel production by improving water use and nutrient cycling. Intercropping also promotes additional ecosystem services including carbon sequestration. These benefits directly impact air, water, and soil quality, which are increasingly challenged by climate change.

Growing switchgrass between rows of poplar trees in Oregon

Southwest Drought Learning Network improves regional drought research and land management. The Southwest Climate Hub (SWCH), through a regionally coordinated approach to drought, communicates stakeholder concerns to researchers and translates science into actionable information and tools. In 2019, three drought workshops attracted more than 130 participants from USDA agencies, Tribes, and other sectors. SWCH provided drought and precipitation information at six additional Tribal meetings, attended by more than 370 Tribal professionals in Arizona and New Mexico. The SWCH also increased precipitation monitoring across the region. Drought related tools and resources were presented at the Universities Council on Water Resources and International Fire Behavior and Fuels annual conferences, leading to actionable science. One of the most important outcomes from these activities is expanding our knowledge of partner and stakeholder needs. These interactions inspired the new Southwest Drought Learning Network that we will continue to develop in 2020.

USDA's Conservation Reserve Program improves water quality of Chesapeake Bay. USDA's Conservation Reserve Program (CRP) is the nation's flagship private-land conservation program and has played a critical role in state and federal efforts to improve the health of the Chesapeake Bay. In the six states contributing to the Chesapeake Bay watershed, CRP has funded over 20,000 riparian (stream area) buffer contracts. To evaluate the performance of riparian buffers in the Chesapeake Bay watershed, a "One-USDA" project was implemented (USDA's ARS, FSA, NRCS, and FS) with support from a broader consortium of researchers that included scientists from U.S. Geological Survey, ARS (University Park, Pennsylvania) and Penn State. They found that riparian forested buffers reduce nitrogen pollution by 17 to 56%, and phosphorus pollution by 4 to 20%, while riparian grass buffers were roughly equally effective. However, filtration of runoff by riparian buffers is regularly undermined by gullies and ditches that route runoff water around buffers, reducing the potential for buffers to treat runoff from adjacent lands by an average of 37% across the study area. Buffers can have significant impact in improving water quality in the Chesapeake Bay watershed, especially when bundled with other conservation practices, resulting in improved quality of surface waters for drinking, recreation and other uses.

Ecological Site Description database improves services provided by federal agencies. Ecological Site Descriptions (ESDs) provide the scientific basis for conservation decisions made by Natural Resources Conservation Service (NRCS) and Bureau of Land Management (BLM) planners, yet this information has not been organized such that it can be readily accessed and integrated with other decision tools. A new version of the web-based Ecosystem Dynamics Interpretative Tool (EDIT) developed by ARS scientists in Las Cruces, New Mexico was released in 2019 based on feedback from NRCS staff across the country. The EDIT database now contains approximately 8000 ESDs and is actively being used for ESD development by NRCS and other agency staff, receiving approximately 250 site visits per day. The database dramatically improves access to ESD information by land managers and the public that is currently in demand but unavailable to them, which in turn allows for more effective land management decisions across the entire U.S.

Improved sensor-based estimates of soil properties. Soil property estimates from in-field reflectance spectroscopy soil sensors are useful for precision agriculture, soil health assessment, and other applications. Estimates of some soil properties may be improved by simultaneous data collection with other complementary sensors, and commercial instruments facilitating this are available. ARS scientists at Columbia, Missouri, and university colleagues investigated optimum data collection and analysis methods for these multi-sensor instruments, identifying a best-performing combination of processing and modeling approaches. In addition, methods were developed and implemented to allow calibrations generated on laboratory data to be successfully applied to field-collected data, improving efficiency of the calibration and estimation process. These results provide information that scientists and practitioners can use to improve in-field sensor based data collection for more informed agroecosystem management.

Nitrous oxide emissions increase exponentially with increasing rate of organic nitrogen sources. Agricultural soils are the primary source of nitrous oxide, a greenhouse gas and the leading cause of stratospheric ozone decay. The relationship between application rates of organic nitrogen sources and nitrous oxide emissions has not been well established. Using a diverse combination of legume-grass cover crop mixes and poultry litter application rates ARS researchers in Beltsville, Maryland, showed that nitrous oxide emissions increase exponentially with increasing organic nitrogen inputs. These results demonstrate that organic amendments can be over-applied to cropping systems. The data can be used to improve greenhouse gas estimation models and by producers who apply organic amendments to help improve nutrient use and reduce the potential for negative environmental impacts.

Balancing nitrogen supply and crop demand to optimize yield, profit, and environmental protection. ARS researchers in Tifton, Georgia discovered that strip tillage (ST) in conjunction with winter cover crops and poultry litter application improved plant nitrogen (N) availability by more than 24 lb/acre/yr in sandy landscapes of the southeastern Coastal Plain via microbial cycling of organic N and reduction of nitrate leaching. Total soil N content increased 27% over five years with ST compared to 22% with conventional tillage (CT). Cumulative nitrate-N leached from soils during the five-year study was 126 lbs/acre (CT) versus 109 lbs/acre (ST). Both of these values were higher than the five year average tile flow N losses of 99 versus 88 lbs/acre, but suggest that leaching from the top 6 in of soil is an important pathway for dissolved N loss from the rooting zone in this landscape. Regardless of tillage, soil microbial biomass N was equal to or higher than soil inorganic N, suggesting that soil microbial biomass is a key factor for retaining N in the rooting zone and thus mitigating soil nitrate loss and protecting the quality of ground and surface waters.

Integration of mixed winter cover crop into no-till dryland cotton sustains yield and improves soil health. Rapid decomposition of low cotton residue under a no-till system in the sub-humid southeastern U.S. enhances the potential of nutrient loss and limits the benefits of a no-till system. Offsite movement of nutrients is a great concern, as it represents an economic loss of applied fertilizers, loss of soil fertility, and downstream environmental degradation. Addition of cool season mixed (grasses and legumes) cover crops to no-till cotton may compensate for low cotton residue, by improving soil water dynamics, soil health, no-till performance and yield. ARS scientists at Mississippi State, Mississippi evaluated the residual effect of cool season cover crops in no-till cotton and soybean fertilized with broiler litter. Results indicated the presence of cover crop residue in no-till cotton improved soil physical characteristics and increased water infiltration, retained nutrients, and increased cotton yield, particularly in drier seasons. Differences in soil moisture content and cotton lint yield between residual mixed cover crop and no cover crop in no-till cotton was more evident in drier periods, with 24.8% and 8.5% greater moisture and yield, respectively, with cover crop than no cover crop management. Additionally, percolation and evaporation during crop growth periods were decreased while water use efficiency increased. These results not only provide useful information for cotton farmers, who are showing interest in cover crop integration, but also scientific knowledge to increase growers' confidence in adopting management practices.