National Program 216- Agricultural System Competitiveness and Sustainability
National Program Annual Report for FY2018

Introduction

Fiscal year 2018 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.

News for NP216 During 2018

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 2018, NP216 scientists participated in research collaborations with scientists from Argentina, Australia, Belgium, Bolivia, Brazil, Canada, China, Colombia, Cyprus, Denmark, Egypt, France, Germany, Greece, Honduras, India, Indonesia, Italy, Japan, Kenya, Lesotho, Mongolia, Mozambique, Namibia, South Korea, Spain, Taiwan, Uganda, United Kingdom, and Uruguay.

During FY2018, 94 full-time scientists working at 23 research units across the U.S. actively engaged in 27 ARS-led and 131 collaborative research projects.

The quality and impact of NP216 research was evidenced during FY2018 by the following:

- 166 refereed journal articles published;
- 4 new material transfer agreements with collaborators; and
- 1 new patent issued and 2 new invention disclosures submitted.

Selected Research Accomplishments for FY2018

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

Incorporating soil health management practices into potato cropping systems lowers disease incidence and increases productivity. Use of longer rotations, disease-suppressive green manures, cover crops, and organic amendments have all been shown to increase tuber yield, reduce disease, and improve soil health in previous potato cropping studies. However, such practices need to be implemented in integrated cropping systems that maintain economic viability for growers. ARS researchers in Orono, Maine, examined ways to incorporate effective soil health management practices into practical potato cropping systems through the establishment of enhanced 3-year rotations with management goals of soil conservation, soil improvement, and disease suppression, in relation to a standard (2-year) rotation and no rotation. Previously established systems were modified to better fit into grower production systems, and evaluated for their effects on soil properties, tuber yield, soil-borne diseases, and economic viability. Overall, the soil improvement system (including compost amendment, reduced tillage, and cover crops) resulted in greater potato yield, higher organic matter and other nutrient contents, and higher microbial activity relative to the standard rotation. The disease suppressive system also increased yield and microbial activity and reduced soil-borne diseases. Enhanced cropping systems also provided comparable or increased net income relative to other 3-year rotations. These results demonstrate that soil health management practices can be incorporated into economically viable cropping systems that can enhance sustainability, productivity, and ecosystem function, and lead to improved agricultural viability and vitality for potato production systems.

Cereal rye cover crops preceding corn can increase incidence of corn seedling root diseases, but improved cover crop management should reduce this risk. In the upper Midwest, corn yields following cereal rye cover crops have been reduced in some years and some fields. One of the possible reasons for the yield reductions is that cereal rye and corn share some of the same root pathogens. Thus, cereal rye may be acting as a host for these pathogens and when cereal rye cover crop is terminated immediately before corn planting these pathogens may be transferred to the corn seedlings. Results from field and controlled-environment studies conducted by ARS scientists in Ames, Iowa, and Iowa State University collaborators, showed that this does occur for Pythium and Fusarium pathogens of corn. The effect of the rye cover crop on these pathogens differed among species, fields, and time after cover crop termination. Understanding the role of cover crops in disease incidence of the following corn crop will allow us to devise management strategies to overcome this risk factor. The impact of this research will be that farmers, extension personnel, crop advisors, and Natural Resources Conservation

Service (NRCS) conservationists will be able to use and manage cover crops more effectively, which will lead to more cover crop adoption, less risk to corn yield, and more environmental benefits.

Unmanned aerial vehicles can provide new understanding of the genetic control of drought tolerance. ARS researchers in Maricopa, Arizona, along with scientists at the University of Arizona and the University of Bologna in Italy, conducted a study to evaluate the use of unmanned aerial vehicles (UAVs) to monitor different genetic varieties of wheat to more rapidly assess drought tolerance and responses. The teams used imagery from two UAVs (also referred to as drones), and data from tractor-mounted instruments to assess the growth stages of 248 kinds of durum wheat under varying water regimes. Results indicated that the UAV-based data explained a larger fraction of variation in crop growth than the tractor-mounted sensors as characterized by the normalized difference vegetation index (NDVI). After reviewing all the data from all the sensor platforms, 46 significant genetic loci showed relationships to the resulting NDVI data, with some of those genetic loci showing concomitant effects on leaf greenness, leaf rolling, and crop biomass. These results demonstrate that relatively low-cost UAVs are effective tools for monitoring crop growth, including specific responses to drought, and will greatly increase the ability of crop breeders and geneticists to dissect physiological responses and to choose crops with better adaptation to drought.

New understanding of water uptake and use in dryland crops. How water stored in soils is used by a growing crop and how that use changes with soil depth is not defined extensively in the literature for dryland crops. ARS researchers in Akron, Colorado, evaluated soil water use by winter wheat, dryland corn, proso millet, and pea over a 21-year period. Previous research in Nebraska suggested that soil water extraction followed a conical water uptake pattern of 40, 30, 20, and 10 percent of total water uptake from the first, second, third, and last one-fourth of the total plant-rooting depth of the crop, respectively. The study confirmed a conical pattern of water use, but showed that under semiarid conditions, the first and second depths demonstrated similar patterns in total water extracted. This research, combined with soil water measurement data in planting and water-use grain yield production equations, will allow producers to determine the probability of receiving a specific economic return and thereby assess the risk in planting one crop versus another.

How does half a century of tillage affect soil nutrients? Long-term nutrient amendment application to soils combined with tillage will affect soil chemical properties. ARS scientists in Akron, Colorado, along with collaborators at Kansas State University, evaluated the influence of tillage and nitrogen fertilizer application on soil nutrient content and soil organic matter after 50 years in a dryland winter wheat-sorghum-fallow cropping system. Long-term tillage reduced soil organic matter content by 33 percent compared with plots that had not been tilled. The scientists also documented no statistically significant change in other plant nutrient levels in soils where only nitrogen was added as an amendment. These results demonstrate that it takes a long time to reduce the availability of soil nutrients in fertile, productive soils. On the other hand, soil quality is quickly lost when soils are tilled in contrast to when they are not tilled. The adoption of no-tillage practices will enable producers to maintain organic carbon, a soil component that will help maintain land productivity.

Wild soybeans as a unique source of ozone-tolerance genes for agronomic needs. Ozone is an air pollutant known to damage sensitive crops such as soybean. Current ozone levels are thought to reduce soybean yields by 10 percent, and rising ozone is expected to further impair crop productivity. To address this threat, ARS researchers in Raleigh, North Carolina, screened 66 wild soybean accessions for ozone tolerance. Several were identified that are tolerant of elevated ozone, and a genetic marker was identified that is associated with ozone tolerance in wild soybean. Breeding experiments are under way to transfer this trait into domesticated soybean. This is part of an ongoing effort to improve the overall tolerance of soybean to a range of abiotic stressors. Introducing beneficial genetic elements via breeding will lead to the development of varieties that can tolerate higher atmospheric ozone levels in general and will provide important ozone-tolerant varieties for use in urban areas, where ozone concentrations can often be higher than in rural areas.

Strip tillage and bean cultivar selection improve crop resilience to drought. Drought stress is a major factor limiting yield of dry bean. Reducing tillage in row crops has an advantage of conserving moisture and increasing water infiltration and may alter the response of dry bean cultivars to drought stress. ARS researchers at Prosser, Washington, conducted field trials for two years to test the ability of different tillage practices and pinto bean cultivars to improve yields under limited water conditions. Strip tillage was determined to benefit dry bean performance under both favorable and limited water conditions, and the bean cultivars PT-11-13, Buster and Montrose were identified as top yielding cultivars under limited water conditions. Combinations of strip tillage with the drought tolerant pinto bean cultivars identified will reduce grower risk of crop failure under drought conditions.

New heat-based weed control equipment enables organic farms to utilize no-till conservation practices. Heat has been used in agriculture in the form of an open flame to control weeds, but the practicality of this approach has needed some refinement. ARS researchers in Auburn, Alabama, focused on utilizing wasted exhaust heat to terminate cover crops and control weeds in conservation systems. The engine's exhaust system was modified by attaching an insulated pipe that transferred exhaust heat to a perforated steel tube that was in direct contact with the flattened cover crop. Findings from two growing seasons indicated the heat system efficiency was 56% and could be improved by shortening and better insulating the pipe that delivers heat to cover crops. Combining the roller/crimper with exhaust heat and supplemental strip heat is a viable option for organic systems where commercial herbicides are not allowed and where effective cover crop termination is essential to cash crop growth. Flattened cereal rye also had higher volumetric moisture contents compared to standing cereal rye, indicating soil water conservation. No differences in volumetric moisture contents were observed between rolled and standing crimson clover, possibly due to denser soil coverage in untreated plots.

Growing cover crops in strawberry furrows reduces soil erosion and improves weed control. Strawberry systems use plastic-mulch covered beds that shed water during winter rainfall, resulting in some of the highest rates of soil erosion in the U.S. Experiments were conducted replacing plastic mulch with winter cover crops of mustard to evaluate mustard growth, nitrogen uptake and weed suppression in strawberry furrows. ARS researchers in Salinas, California, determined that, compared with bare furrows, high seeding rates of mustard reduced weed growth by 40% but that hand weeding is needed to provide adequate weed control. This research provided growers with the first information on cover cropping with mustard in strawberry furrows and the potential to radically improve the sustainability of organic and conventional strawberry production in this region of California.

Surface application of lime in no-till systems improves soil properties. Fertilizer nitrogen application and the lack of tillage-based mixing in continuous no-till farming can acidify soils that inevitably require pH neutralization. ARS scientists in Pendleton, Oregon, and Pullman, Washington, investigated the effect of surface application of lime on the composition of soil microbial communities in Palouse, a dryland cropping region of the inland Pacific Northwest. Sampling at three-fourths inch depth increments of soil revealed a layering (or stratification) of the microbial communities and soil chemistry which would have been otherwise obscured by sampling at four-inch depth increments. Within six months of lime application, the soil pH increased in the top three-fourths inch increment and by 18 months, treatment-based changes in the bacterial communities were observed but only in the top 1.5 inches of soil. Growers and their advisors now have a timeline for expecting when liming will take effect in no-till systems and how the soil profile should be sampled to properly account for soil biological and chemical properties.

Inclusion of perennial forages in cropping systems enhances crop yields and improves soil health. Perennial forages have the potential to diversify annual crop rotations and provide ecological and agronomic benefits, but guidance for producers regarding their effective use is lacking in semiarid regions. Specifically, the length of time needed under perennial forages for soil health and crop productivity improvements to occur is unclear. ARS scientists at Mandan, North Dakota showed that wheat yields following just 2 years of alfalfa were similar to yields of a fertilized, continuous spring wheat control, and an alfalfa phase of 3 years or more resulted in spring wheat yields greater than the control. Relative to annual cropping, perennial forages slowed soil acidification, increased the portion of soil organic matter that is rapidly degradable, and improved soil physical conditions. Soil responses to perennial forages occurred as soon as 2 years after forage establishment but peaked 4 years after establishment. Among perennial forages, intermediate wheatgrass alone or mixed with alfalfa was most effective at improving soil. Yield benefits persisted for at least four years following conversion from perennial forages. Producers in semiarid no-till systems can use these results to develop profitable management strategies for including perennials in annual cropping systems.

Innovative approaches for remotely monitoring land surface conditions in rangelands. Improved remote sensing and data acquisition technologies are needed to map and monitor rangeland vegetation. ARS scientists in Las Cruces, New Mexico, identified vegetation indicators of drought and drought recovery using time series satellite imagery. An existing data tool (Breaks for Additive Seasonal and Trend Monitor, or BFAST-M algorithm) was refined to evaluate seasonal vegetation change from satellite images and to identify locations of greatest plant recovery from drought. This tool and its inclusion in an evaluation process can be used to monitor large landscapes to identify areas of greatest impact and recovery from drought on western rangelands. A phenology research initiative for the Long-Term Agro-Ecosystem Research (LTAR) network was established and ARS scientists collaborated with colleagues at 16 other sites to identify tools such as BFAST-M for analyzing and synthesizing remotely sensed imagery at sites across the LTAR network. Land managers and producers will benefit from these new technologies to remotely determine vegetation characteristics and forecast productivity to improve sustainable agricultural productivity.

Integrative animal and environment models enable producers to predict and prevent animal disease outbreaks. Vector-borne diseases such as vesicular stomatitis virus (VSV) have major economic implications for animal agriculture globally. ARS scientists in Las Cruces, New Mexico are collaborating with others to retrospectively integrate environmental, vector, host and viral variables with disease occurrence in an effort to predict future occurrence and distribution of vector-borne diseases. Proximity of surface waters to VSV occurrences were analyzed to inspect the relationship between water bodies and the transmission of VSV between vectors and hosts. VSV genetic data were also examined with respect to geographic locations to build phylogenetic trees and describe the distribution of genetic lineages across the western U.S. in an effort to identify outbreak and dispersal pathways. Finally, vector-related proactive mitigation strategies were examined that could be employed by producers at the premise level and suggested for broader use by animal health professions to reduce economic costs of quarantine designation during VSV incursions and outbreaks.

Matching cattle breed grazing behavior with available forage resources improves system resilience. New world cattle biotypes may be one strategy for ranchers to cope with low and variable forage production often associated with semiarid rangelands in the western U.S. Raramuri Criollo cattle have undergone approximately 500 years of natural selection and adaptation to harsh rangeland conditions. However, their calves tend to be smaller and take longer to achieve marketable weight. ARS scientists in Las Cruces, New Mexico compared foraging behavior of grass-fed Criollo steers to crossbred steers from Criollo cows and Brangus sires. Preliminary data suggest Criollo and Criollo crossbred steers exhibited similar movement and spatial distribution patterns. Both groups demonstrated desirable grazing behavior traits previously observed with Criollo cows on extensive desert landscapes. Identifying biotypes with foraging strategies that match forage resources in extensive semiarid ecosystems will benefit ranchers by optimizing use of available forage.

New method developed to assess both pastures and rangeland provides integrated grazing land management options. Currently separate methodologies are used for assessing the ecosystem function (biology, hydrology, soils and livestock production potential) of pastures and rangelands. An integrated grazingland assessment method was developed based on a need to treat both rangeland and pasture livestock production systems as resilient agro-ecological enterprises. Scientists from Mandan, North Dakota, in conjunction with scientists from Texas A&M AgriLife, Virginia Tech, and Noble Foundation, evaluated resilient forage production practices in the U.S. and provided ways to assess and monitor these grazinglands for optimum and sustainable productivity based on land potential. This methodology is being considered for inclusion into USDA-NRCS Natural Resource Inventory that is a nationwide assessment of natural resources across the U.S. and may be used on millions of acres of privately owned rangelands across the U.S.

Organic compost application improves dryland forage yields and soil quality. The public's interest in organic agriculture has increased in recent years. ARS researchers in Akron, Colorado, evaluated three beef feedlot compost treatments on two dryland organic cropping systems, a wheat-fallow rotation harvested for grain and a triticale + pea–fallow rotation harvested for forage. They assessed the effects of three different rates of biennial compost applications: none, 23 tons/hectare, and 109 tons/hectare. The triticale + pea biomass responded positively to the highest compost treatment. Beef feedlot compost had a positive effect on grain zinc content but did not increase grain yields. Soil carbon and nitrogen contents increased with the highest compost rate, and soil quality, as measured by microbial enzymes, was improved by the high compost treatment. These results provide science-based documentation for organic producers showing the value of beef feedlot compost in enhancing forage yields, wheat grain quality, and soil quality. The increase in grain zinc content is of particular interest because zinc nutrition is critical in early childhood development and health.

Using cover crops as forage improves profitability of soil conservation. The traditional 2-yr rotation of spring wheat followed by summer fallow helps decrease the risk of crop failure in the short term, but long-term consequences include soil carbon depletion, formation of saline-seeps, degraded environment for soil microbiology, loss of habitat for fauna including pollinating insects, reduced soil water holding capacity, and inefficient precipitation storage during fallow with about 60 to 85% of precipitation lost to surface evaporation. Interest among wheat growers in utilizing diverse cover crop mixtures to enhance soil quality is increasing but the lack of immediate financial return on the cost of seeding a traditional cover crop discourages many growers from adopting this practice. However, little is known about replacing the fallow phase in wheat-fallow rotations, for example with a multispecies crop harvested for forage with regrowth left to serve as a standing cover crop. ARS researchers in Sidney, Montana initiated a 6-year study to investigate the production potential of a 10 species crop mix (buckwheat, canola, cowpea, flax, lentil, millet, pea, radish, sorghum, turnip) in place of fallow in 2-year durum rotations. Results from the first 3-year period of the study indicate planting a multispecies crop mix in place of fallow provided on average 1.4 tons per acre (59% of which was radish and pea) of high-quality forage harvested in early summer and an additional 2.4 tons per acre (50% of which was sorghum and millet) unharvested biomass at killing frost left for standing cover to increase ecosystem services compared to fallow. Results from this research show that utilizing a portion of the cover crop growth as forage may offset seeding costs enough to make adoption more economical.

Conservation tillage improves water quality in an integrated crop-livestock system. ARS researchers in Tifton, Georgia, found that strip tillage (ST) in conjunction with winter cover crop planting and poultry litter application improved plant nitrogen availability by more than 24 lb/acre/yr in sandy landscapes of the southeastern Coastal Plain via microbial cycling of organic nitrogen and reduction of nitrate leaching. Total soil nitrogen content increased 27 percent over 5 years with ST compared with 22 percent with conventional tillage (CT). Cumulative nitrate-nitrogen leached from soils during the 5-year study was 126 lb/acre (CT) versus 109 lb/acre (ST). Both of these values were higher than the 5-year average tile flow losses of nitrogen but suggest that leaching from the top 6 inches of soil is an important pathway for dissolved nitrogen loss from the rooting zone in this landscape. Regardless of tillage, soil microbial biomass nitrogen was equal to or higher than soil inorganic nitrogen, suggesting that soil microbial biomass is a key factor for retaining nitrogen in the rooting zone and thus mitigating soil nitrate loss and delivery to ground and surface waters.

Integration of poultry litter into a cover crop in a no-till cotton field improves soil health. Upland soils are generally low in inherent nutrient content, marginal in organic matter, and vulnerable to erosion and nutrient losses, all of which can negatively affect crop production. Planting cover crops and applying poultry litter may be a combined strategy to boost no-till performance by improving soil physical properties. Clear support for the benefits of these practices within Mississippi, however, remains limited, and more information is needed to elucidate these benefits and encourage their adoption in the state. ARS researchers in Mississippi State, Mississippi, investigated the effects of a cover crop along with broiler litter fertilization on cotton performance and soil health. Addition of a cover crop alone served as a nitrogen scavenger compared to no cover crop, but the cover crop also improved soil physical properties by reducing bulk density and enhancing infiltration and hydraulic conductivity. Furthermore, the combined integration of a cover crop and poultry litter application increased soil organic carbon concentrations, which was positively correlated with soil physical properties. Results from this study will aid farmers and stakeholders in the mid-South to better understand the benefits of combining cover cropping and poultry litter amendments.

Component 2. Increasing Efficiencies for Agroecosystem Sustainability

Increasing crop diversity increases economic returns and reduces risk. Increasing crop diversity by growing a larger variety of crops in rotation has been proposed to increase sustainability; however, for producers to adopt these rotations as standard practice, they need to be profitable. In a long-term crop rotation study, ARS researchers in Mandan, North Dakota, showed that crop productivity and economic returns increased with increasing crop diversity, whereas economic risk decreased. In most cases, increasing crop diversity also resulted in higher soil organic carbon levels, which allows producers in the region to simultaneously realize economic benefits of $25 to $83 per acre while maintaining or building soil organic carbon.

Development of a transplanter for a walk-behind tractor (U.S. Patent number: U.S. 10,004,174 B2) enables small farm producers to use conservation practices. Vegetable production on small farms has predominately relied on hand labor including hand transplanting, which involves physically strenuous exertion due to continuous bending and stooping. Small farm producers who have walk-behind tractors expressed an urgent need to develop a mechanical transplanter to transplant vegetables into cover crop residue that can be adapted to small scale tractors. To address this need, an ARS researcher at Auburn, Alabama, developed and patented a power take off (PTO)-driven micro-transplanter to work with a self-propelled walk-behind tractor for no-till and/or organic vegetable small scale market farms and gardens. Development of a lightweight compact transplanter powered by a PTO shaft allows producers to utilize these power units to effectively transplant vegetable crops. The transplanter is operated by one person who simultaneously operates the walk-behind tractor. In contrast, larger commercial transplanters must be operated by at least two people; one for the transplanter and one person to drive the tractor.

Precision application of poultry litter benefits cotton production. Farm soils are inherently variable. A small field may have areas of high and low soil organic matter, high and low elevations, and heavy and light soil texture. Applying the same amount of poultry litter or other manures from one end of such fields to the other leads to applying excess in some parts and not enough in others. ARS researchers at Mississippi State, Mississippi, used site-specific technology to test if applying poultry litter according to the soil organic matter (SOM) level or the field contour would improve cotton yield or reduce cost of production. A poultry litter application prescription was prepared so that high amounts were applied in parts of the field with high elevation or with low SOM and low amounts were applied in parts of the field with low elevation or high SOM. The results showed that prescription-based application targeting the need of the cotton may reduce cost of production without sacrificing yield. Cotton fertilized with litter regardless of the method produced more lint yield than cotton fertilized with conventional synthetic fertilizers. Applying the litter by varying the rate based on elevation (or SOM) where higher rates are applied at higher elevations (or lower SOM) and lower rates at lower elevations (or higher SOM) may further enhance the superiority of litter. These results are most useful for cotton farmers in the southeastern U.S. in farms with SOM and elevation variability great enough to affect production and profit.

Early leaf sampling improves fertilizer use efficiency for soybean. Rapid/early detection of nutrient stress in soybean is an important component of in-season crop management to minimize crop losses. The traditional approach is to sample upper leaves to determine nutrient status, but the question of when the optimal time to sample the leaves during the crop life cycle still needs to be identified. ARS researchers at Beltsville, Maryland, found that relationships between nutrient status (phosphorus and potassium levels) and seed yield were best established when leaves were sampled earlier in the season (within 4 to 5 weeks after planting). These relationships were less significant if leaf samples were taken later in the growing season, likely due to remobilization of leaf nutrients as the plant ages. The results can improve management of fertilizers in the field and lend towards more efficient sampling dates.

Improved assessments of carbon and energy footprints of intensified rotations with oilseeds under low rainfall. Many dryland wheat growers in the Pacific Northwest are not aware that some management practices can reduce their farm carbon and energy footprints. ARS scientists in Pendleton, Oregon, compared the overall cradle-to-farmgate carbon footprint and cumulative energy consumption of 2-year (fallow/crop) and 3-year (fallow/crop/crop) rotations with various cereals and oilseeds considering the low rainfall conditions in eastern Oregon.

When comparing the cost of fossil fuel energy invested to the bioenergy return for oilseed oil production, there were net positive returns of nearly a factor of two to four across all spring and winter varieties. More broadly, they found that from a trade-off comparison—total dollar value versus carbon dioxide equivalent emissions per acre over 6 years—that fallow/winter wheat and fallow/winter oilseed were shown to be the most promising for producers, offering both low emissions and high value. Growers now have new information on key crop inputs that are the most economically beneficial and that are drivers of greenhouse gas emissions, which will assist and guide them to modify agricultural chemical application, tillage, crop selection, and crop rotation practices.

Improved crop water models inform irrigation scheduling, leading to increases in water-use efficiency of irrigated corn. To accurately predict the growth of corn (maize), maize growth models must accurately simulate the water used by the crop to account for how many days of growth can occur following a rain or irrigation event before the soil water supply is exhausted. Therefore, under the umbrella of the Agricultural Model Inter-comparison and Improvement Project (AgMIP), an inter-comparison test was organized using eight years of water use or evapotranspiration (ET) measurements collected by an ARS researcher at Ames, Iowa, as the standard for evaluations. An ARS collaborator at Maricopa, Arizona, compiled four stages of model comparisons (wherein the modelers were given progressively more information) of ET predictions from 29 models from 28 research groups around the world (including ARS researchers at Maricopa, Arizona and Beltsville, Maryland). In the first "blind" phase for which only weather, soils and management information were furnished to the modelers, estimates of seasonal ET varied from about 200 to about 700 millimeters, and in subsequent phases, the range of ET predictions, as well as yield, remained large. Nevertheless, several models performed substantially better than the median for predicting ET and grain yield. Approaches used in the better models thus indicate options for improving all the models and ultimately, estimations of crop water use, which strengthens management and policy decisions by stakeholders ranging from producers to national leaders.

Smart soil moisture sensors improve irrigation water-use efficiency. Better irrigation scheduling is one of the most critical aspects of irrigated agriculture for improving yield and reducing the adverse impact on quality of surface and ground waters. In team research, ARS scientists in Sidney, Montana conducted a field study at two locations of different soil texture, one in North Dakota and the other in Montana. Their goal was to evaluate HydraProbe, Campbell Time Domain Reflectometry and Watermark real-time soil moisture sensors for their ability to estimate water content in sandy loam and clay loam soils. Results showed that the three sensors provided different estimates of soil moisture contents in both soils. Nevertheless, their work suggests that soil moisture sensors including those used in this study can be suitable for irrigation scheduling without in-situ calibrations by simply setting the upper and lower irrigation trigger limits for each sensor and each soil type. The upper trigger point occurs directly after an irrigation event and the lower trigger point is based on about 50% depletion of available water in the crop root zone and it occurs prior to irrigation refill. This approach can help irrigators to achieve their irrigation scheduling and productivity goals without consuming any time on sensor calibration. The approach requires minimal training and labor, and it can provide useful information to aid producers to determine when and how much to irrigate without causing any damage to their crops, thereby optimizing crop productivity while maintaining environmental quality with minimal water loss.

Precision management of a grain cropping system improves yield stability. Targeting crop management practices and inputs using precision agriculture can help meet sustainability goals, including simultaneously improving crop yields and reducing environmental impacts. ARS scientists at Columbia, Missouri, assessed the impact of ten years of a field-scale precision agriculture system (PAS) on grain production. The PAS system included no-tillage, cover crops, winter wheat instead of corn on areas with shallow topsoil and low corn profitability, and variable-rate fertilizer application. This research showed that the PAS maintained, but did not increase, grain yield. However, the PAS did result in less variation in yield from year to year in many areas of the field, despite more extreme weather conditions than in the previous ten year period under conventional management. Thus, yield may be more stable with precision agriculture and conservation management. This information will help increase the use of these practices by farmers and farm advisors on these and similar soils.

A variability/vulnerability index identifies opportunities for precision agriculture to increase crop production efficiency. Prior to investing in precision agriculture tools and technologies, it would be advantageous for producers and their service providers to have a quick way to screen fields for variability. ARS scientists at Columbia, Missouri, in cooperation with scientists at the University of Missouri, developed maps of Missouri that identified where fields had the most variable soils and were most vulnerable to erosion. Although the benefits of precision agriculture are heavily situational and dependent on the specific variation present within a field, this research will help producers and their providers get a general idea of which fields and regions have the greatest potential for optimizing agricultural inputs using precision agriculture technologies.

Climate-smart decision-making technologies and services that enable farmers to lower risks. Scientists at the USDA Southwest Regional Climate Hub (SW Hub) promoted the establishment of partnerships with Arizona, California, Hawaii, Nevada, New Mexico, and Utah to develop climate-smart decision-making tools and provide regionally relevant climate related services. For example, the SW Hub and ARS scientists worked with the USDA Risk Management Agency to build the AgRisk Data Viewer, a national data viewer and download platform that provides cause-of-loss and indemnity data by crop from national to county scales. The SW Hub also established and provides support to a network of climate extension professionals who focus on regionally relevant climate adaptation. In addition, the SW Hub hosts a website and sends out regular bulletins. The SW Hub and its partners hosted the 86th Western Snow Conference and initiated a partnership with the Natural Resources Conservation Service to develop and deliver information about air quality and dust mitigation related to agricultural practices and future climate. The SW Hub thus strives to develop, synthesize, and provide information to assist Southwestern U.S. farmers, ranchers, and foresters in strategically adapting to the impacts of climate change.

Component 3. Reaching Agroecosystem Potential

Improved crop models improve assessment of wheat yield potential in future climate scenarios. Global warming will likely affect future crop productivity, so it is important to be able to estimate the effects of high temperatures on crop growth to assist producers and improve assessments of global food security. Therefore, from 2007-2009, ARS researchers in Maricopa, Arizona, and a collaborator from the University of Arizona, conducted a Hot Serial Cereal experiment ("Cereal" because it was on wheat, "Serial" because the wheat was planted serially about every six weeks for two years, and "Hot" because on six of the planting dates infrared heaters were deployed in the field to warm a third of the plots). Subsequently, using data from this experiment and trials elsewhere in the world, the performance of 30 wheat models was compared. From this work, new and improved temperature response functions were derived to simulate multiple plant physiological processes. Incorporation of these improved response functions will improve estimations of wheat growth and yield, ultimately leading to better crop management practices and cultivars for warmer production environments.

Switchgrass yield is usually water-limited, but may become nitrogen-limited in wet years. Under global change, precipitation is expected to become more variable, resulting in both longer dry spells and more intense periods of precipitation. Increased precipitation variability will therefore have significant consequences for bioenergy feedstock production. In an experiment applying precipitation treatments at five levels representing from 50% below to 50% above ambient precipitation levels, ARS researchers in Temple, Texas, found that precipitation at or below ambient levels reduced switchgrass biomass compared to levels simulating greater than ambient precipitation, indicating that switchgrass growth is water limited under average precipitation levels. By analyzing data on switchgrass biomass production from nearly 50 publications, we showed that during wetter years when water may be less limiting to switchgrass biomass production, nitrogen may instead limit switchgrass biomass production.

Conservation tillage is key to storing carbon in the soil in future climate scenarios. In the western Corn Belt, future growing season conditions are projected to be warmer with more variable precipitation. A better understanding of how these conditions will influence crop production and soil quality is needed. ARS researchers in Lincoln, Nebraska used long-term soil and crop production data to validate a soil carbon model (CQESTR) and then used the validated model to estimate changes over a range of tillage practices (chisel, disk, ridge, and no-tillage) and crop rotations (continuous corn or corn – soybean) assuming either that yields would continue to increase at a rate similar to the last several decades or would decline due to negative temperature effects. Changes in soil carbon were estimated under weather conditions projected for 2065. With increasing yields, soil carbon increased slightly or was maintained with conservation tillage (no tillage or ridge tillage) but grain yields declined with conventional tillage (disk or chisel tillage). Results suggest that soil carbon can only be sustained under projected climate change if current trends in biomass yield continue and conservation tillage is used.

Alfalfa captures carbon under semiarid conditions. Carbon sequestration in pastures can be particularly effective given limited soil disturbance, minimal erosion, and continuous carbon input from above- and below-ground biomass during the growing season. Information about carbon sequestration potential from pasture management systems is lacking, particularly in semiarid regions. ARS researchers at Mandan, North Dakota conducted a study from 2009 to 2013 to determine the daily, seasonal and annual carbon budget of hayed alfalfa and grassland. Alfalfa was found to be a moderate carbon sink, whereas grassland was a carbon source. Alfalfa was also found to be highly efficient at capturing carbon in both warm/dry and cool/wet growing seasons. These results are useful to producers in selecting forages that can serve as a nitrogen source while improving soil quality. These results are also useful to policy makers and action agencies assessing the capability of forages to store carbon across a range of weather conditions in a semiarid region.

Trees store carbon underground as well as above-ground. Understanding how soil organic carbon (SOC) changes under agroforestry system will help define the benefits of incorporating tress into landscape management. Tree windbreaks are a common practice in the Great Plains as these porous barriers enhance crop yields through reduced wind speed and evaporation. Many windbreaks are old and in need of renovation. ARS researchers at Ames, Iowa, collected soil profile samples to 1.25 m depth from 8 sites in 4 states to measure soil organic carbon (SOC) stocks and compare these values with adjacent crop fields. The amount of SOC beneath tree windbreaks was significantly greater than the cropped fields at 5 of the 8 sites. Existing trees can be removed and used for bioenergy feedstock and replaced with fast-growing or better adapted species that will likely continue to enhance SOC accumulation in the profile.

Additional measures of SOC effects on soil health indicate that the tree windbreaks also enhance overall soil health. The results indicate that there is variation in SOC distribution due to climate, soil, tree species and crop management.

Nitrate contamination of surface water is a major water quality concern in the Upper Midwest. Some of the negative environmental impacts associated with conventional agricultural production have encouraged producers to investigate alternative management practices, including organic farming methods. In 2011, ARS scientists in Ames, Iowa, initiated a long-term study that compares tile drainage water losses of nitrogen in the form of nitrate (nitrate-N) in a conventional corn-soybean and an organic corn-soybean-oat/alfalfa-alfalfa organic grain cropping system. Between 2012 and 2014, average annual nitrate-N concentrations were lower in tile drainage water collected from the organically managed rotation compared with water from conventionally managed rotation. Total nitrogen loss from 2012 to 2014 through conventional rotation (79.2 kg nitrogen/ha) was nearly twice as much as that through organic rotation (39.9 kg nitrogen/ha). These results suggest that organic farming practices can reduce nitrogen loss and thus improve water quality in Midwestern tile-drained landscapes.

Using phosphorus sorption materials in bio-retention cells improves water quality. Excess phosphorus (P) transported to surface waters from the landscape is a significant contributor to eutrophication and poor water quality. Bioretention cells (BRC) are an urban best management practice (BMP) that work by mitigating both water quantity and quality through slow release of runoff water and filtering of nutrients such as P. A new technique for BRCs includes use of fly-ash as a P filter material, thereby making the BRC a type of P removal structure. ARS researchers at West Lafayette, Indiana, examined the effectiveness of several BRCs that were in operation for several years. The filter media was sampled to a depth of 0.6 m and tested for different forms of P. Most of the P was captured in the upper 15 cm of the BRCs. Overall efficiency of the BRCs with fly-ash ranged from 68-75% in reducing P concentration, and 76-93% in reducing P mass (i.e. load). The appreciable measured P reduction illustrates how this BMP can serve as an effective tool at reducing dissolved P losses to surface waters through a simple modification of BRCs.

New dicamba formulations have minimal impacts on the microbial activity in the soybean rhizosphere. After the introduction of glyphosate and Roundup Ready crops in 1996, farmers have relied heavily on this herbicide/crop system combination for weed control. Unfortunately, the use of glyphosate has resulted in the development of resistant weed biotypes. To combat these resistant weeds, crops engineered with resistance to different herbicides, including dicamba, are being introduced. Although these herbicides are powerful weed suppressors, they can alter plant physiology and sometimes are exuded from roots, potentially affecting beneficial soil bacteria in the rhizosphere (the region of soil closely associated with root tissues). ARS researchers in Stoneville, Mississippi, conducted greenhouse experiments to assess the effects of two new dicamba formulations on the rhizosphere microbial community of dicamba-resistant soybean plants. Rhizosphere soil samples were collected at several times up to a month after dicamba application and tested for microbial activities of enzymes linked to carbon, nitrogen, and phosphorus cycling in soil. Application of dicamba resulted in a small but temporary decrease the activity of an enzyme linked to nitrogen mineralization, whereas other activities linked to phosphate and carbon cycling were unaffected. All activities in dicamba-treated rhizosphere soil were similar to those of untreated soil by 3 days after herbicide application. This research demonstrates that farmers can use new dicamba formulations on resistant soybeans with no adverse effects on microbial activities in the rhizosphere.

Assessing the feasibility of a forest-to-farm biochar paradigm. The upcycling of low-value forest biomass has considerable potential to offset the cost of wildfire risk reduction in national and private forests. The production of biochar simultaneously consumes low-value biomass and produces stable charcoal that, when applied to dryland agricultural soils, can increase water holding capacity and improve crop yield. In this way the production of forest-origin biochar has the potential to promote forest restoration, foster forest-related employment, increase agricultural production, and sequester carbon. Biochar offers the greatest opportunity where dryland food crops, limited water availability, existing energy transmission infrastructure, and high-fire risk forests share the same landscape. Researchers in Corvallis, Oregon, in collaboration with researchers from Oregon State University developed strategies to optimize wildfire hazard reduction treatments, biochar facility locations, and agroeconomic outcomes to evaluate the costs and benefits of a forest-to-farm biochar paradigm. The results of this study suggest that biochar application, even at high rates, is economically feasible for high-value crops including potatoes, alfalfa, and organic row crops.

New image-processing method enables assessment of pollination benefits of cover crops. Flowering cover crops have the potential to be beneficial for pollinators. Sunflowers, a component of the natural landscape in North America, are often included in cover crop seed mixtures to support pollinating insects, and the size of flowers (floral display) can be important in attracting pollinators. Measurements of sunflower heads are also important for estimating seed yield. However, measuring the sunflower head, disc, and ray florets (petals) by hand can be subjective and time-consuming. An image processing method was developed by ARS scientists from Mandan, North Dakota and Fargo, North Dakota and scientists from North Dakota State University to give more accurate and objective measurement than manual methods, decreasing time and labor in the field. An added benefit is the potential use of this method by growers to estimate seed yields.

Decision support tools help growers select biochars to improve soil health and economic return. Despite the known agronomic benefits of biochar, few farmers have adopted biochar-based strategies to improve soil health or increase plant productivity primarily because standards and agronomic recommendations regarding application rates and techniques are lacking. ARS researchers in Corvallis, Oregon, in collaboration with researchers from Oregon State University, published the Pacific Northwest (PNW) Biochar Atlas, a suite of decision-support tools designed to alleviate uncertainty regarding the use of biochar on farms. The atlas includes a soils property explorer that allows users to identify soil deficiencies in soils across the PNW. A biochar selection tool pairs these deficiencies with biochar types best suited to their soil needs and crop type and calculates the carbon sequestration, fertilizer, and liming value of amending at different rates. A cost-benefit calculator determines the cost savings from offsetting fertilizer, lime, and irrigation water, and potential income from increased crop yield. The website is useful for both growers and researchers and has had nearly 20,000 page visits in the first 6 months, with visitors from 75 countries.

An adaptive nitrogen management decision support tool has been improved for use with cover crops. Growers need decision support tools that can estimate nitrogen release from cover crops in real-time to make robust fertility management decisions. The concentration of carbon and nitrogen in cover crop shoot and root biomass influences the rate of nitrogen release from decomposing cover crops but these data are not often collected under a wide range of conditions. ARS scientists in Beltsville, Maryland, collected these types of data and used them to calibrate and test the Adapt-N simulation model. Results improved the ability of Adapt-N to predict nitrogen release from terminated cover crop mixtures, which will help improve nitrogen management in U.S. agriculture, thereby saving farmers money and reducing environmental impacts.

Development of the Land-Potential Knowledge System (LandPKS) app enables producers to make more sustainable land use decisions. Land managers in the U.S. currently lack an efficient system for accessing and sharing knowledge about land management that is relevant to the potential of their land. Because land potential depends on soil, topography and climate, the identification of appropriate management systems begins by matching areas with similar conditions. ARS scientists in Las Cruces New Mexico continued development of the LandPKS app on iOS and Android phones and tablets allowing managers to rapidly collect and store soil and topographic information (LandInfo) and monitor vegetation (LandCover) of a given area. They also refined algorithms to identify soils based on user inputs, implemented a more precise and accurate tool for determining soil color using smartphone cameras, completed an analysis of soil texture determinations by citizen scientists, and developed an international standardized system for automatically determining Land Capability Class on the phone based on user inputs.

These tools will be combined with other apps to develop information databases for identification of management options for enhanced global land productivity and sustainability.