National Program 216- Agricultural System Competitiveness and Sustainability
National Program Annual Report: FY2013

Introduction

The USDA-ARS National Program for Agricultural System Competitiveness and Sustainability (NP 216) had a productive and dynamic year in FY 2013. Scientists in NP 216 continue to make important impact in diverse areas of research to help producers develop integrated solutions that solve their problems related to productivity, profitability, and natural resource stewardship.

FY2013 featured publication of a new Action Plan for NP 216 and development of five-year research plans (2103-2018), all of which were developed from comprehensive stakeholder input gleaned from the national stakeholder workshops. These efforts are documented online at: http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=216 and include workshop documents, strategic vision, the action plan, and accomplishment and external assessment reports.

Background

Increasing demands are being placed on agriculture. The public demands a safe, affordable supply of high quality, nutritious food, a healthy environment, a growing economy that provides a comfortable standard of living for its citizens, and increased use of renewable sources of energy. Agriculture must meet these demands using an area of land that has not changed appreciably over the last 100 years and a workforce that has decreased from nearly 50% to less than 5% of the population over that same period.

Agricultural production over the past decades has become much more productive and efficient. These improvements have been accomplished through:

- increased use of conservation tillage practices
- expanded use of irrigation
- increased use of fertilizer and improvements in nutrient management
- development and deployment of pesticides to reduce losses associated with weeds, insects, disease, and other pests
- genetic improvements (including genetically modified organisms, GMO’s) for crop management, improved traits, and increased yields
- improvements in equipment
- advances in crop processing and storage
- an infrastructure that facilitates timely distribution and export of agricultural products.

Similar advances will be needed in the future to meet societal demands, and modern agriculture must confront a number of major challenges. The U.S. and global populations are growing rapidly, and agricultural productivity must increase to meet their food and fiber needs. The portion of populations involved in agricultural production is small and declining, as a majority of people live in urban areas. Large segments of the population are thus unfamiliar with what agriculture provides and how it is provided. Housing and infrastructure needed to support a growing population and migration of people from rural to urban areas has resulted in urban encroachment into productive agricultural areas and increased conflict between urban and rural life styles (e.g. odor and dust issues, increased traffic, and land use changes). There is increasing competition for other resources essential to agriculture. In many U.S. regions, water supplies will likely not meet future demand for human consumption, agriculture, and environmental stewardship. Agriculture is a major energy consumer, and there are calls to increase use of agricultural land to produce feedstocks or biofuels that reduce dependence on foreign energy. Finally, agriculture will be required to reduce greenhouse gas emissions and sequester carbon to help mitigate climate change, and develop or shift practices to adapt to climate change.

The goal of the NP216 National Program is to conduct research that addresses the challenges described above, and specifically to provide farmers with management practices, decision aides, and information needed to move farming systems along a trajectory toward greater sustainability. The program has four problem areas:

1. *Food, feed, fiber, and feedstock production systems.*
   - Research addresses systems producing food (e.g. wheat, rice, peanut, vegetables, fruit), feed (e.g. soybean, corn, alfalfa), fiber (e.g. cotton), and feedstock (e.g. crop residue, oilseed, perennial biofuel crops), and is designed to understand the underlying agroecological principles for developing technologies and production strategies for generating food, feed, fiber, and feedstock.
2. *Production system economics*
   - Research addresses the profitability of agricultural production systems, and is designed to understand the economic factors affecting production system profitability and to develop strategies for profitable food, feed, fiber, and feedstock production.
3. *Production system effects on natural resource*
   - Research addresses soil, water, and air resources associated with production systems, and is designed to understand the physical, chemical, and biological processes in production systems and develop strategies for meeting air, water, and soil quality expectations of society.
4. *Integration of sustainability goals*
   - Research addresses problems related to synthesizing data needed to assess sustainability at the farm/regional/or larger scales. This synthesis is necessary to insure that progress is being made in all sustainability goals. Research is designed to develop and use databases, analytical tools for processing datasets, statistical methods, assessment tools, and models to synthesize results and compare systems at various scales.

Specific research topics include production systems for commodity and specialty crops; integrated crop – livestock systems; organic production systems; micro- and macroeconomic implications for these systems; and production system effects on air, water, and soil quality. During FY 2013, 64 full-time scientists working at 24 research units in 16 states across the U.S. actively engaged in 80 ARS-led and collaborative research projects.

Personnel items in NP216

New scientists in the NP216 team in FY 2013 are:

- **Dr. Guanglong (Gary) Feng,** Soil Physicist; Genetics and Precision Agriculture Research Unit, Starkville, MS. Dr. Feng received his education in China and spent several years in a Post-Doctoral position working with Dr. Brenton Sharratt of ARS in Land Management and Water Conservation Research at Pullman, Washington.

- **Dr. Kristin Trippe** was hired as a Research Microbiologist at the Forage Seed and Cereal Research Unit in Corvallis, Oregon. Kristin received her PhD in 2007 from Oregon State University. Prior to her appoint, she worked as a post-doc with Dr. Gary Banowetz. Her research characterizes microbes and microbial products that impact agricultural systems and soil productivity.

The following scientists retired from the ranks or left ARS:

- **Robert Evans**, Pest Management Research Unit, Sidney, MT.
- **Andy Lenssen**, Pest Management Research Unit, Sidney, MT.
- **Gretchen Sassenrath**, Crop Production Systems Research Unit, Stoneville, MS.
- **Ben Coffman**, Sustainable Agricultural Systems Laboratory, Beltsville, MD.

The distinguished record of service of these scientists is recognized world-wide, and they will be missed in NP216.

The following scientists in NP 216 received prominent awards in FY 2013:

- **Liwang Ma, Greg McMaster, Laj Ahuja, James Ascough, and Tim Green** received the Colorado Governor Award for High Impact Research for the RZWQM model.
- **Liwang Ma** received the Environmental Quality Research Award from the American Society of Agronomy.
- **Laj Ahuja** received the International Soil Science Award from the Soil Science Society of America.
- **Johnie Jenkins** received the Lifetime Achievement Award from the National Association of Plant Breeders.
- **D.S. Long** received the Outstanding Associate Editor from the Agronomy Journal
- **David Archer** received the Conservation Research Award from the Soil and Water Conservation Society.
- **Dexter Watts** received the 2013 Early Career Award from the Southern Branch ASA, and the 2013 Inspiring Young Scientist Award from the Environmental Quality Section of ASA,

The quality and impact of NP 216 research was further evidenced in FY 2013 by the following:

- Over 90 refereed journal articles published
- 1 new cooperative research and development agreements with stakeholders
- 8 scientific models updated or developed
- Administration or development of 3 web sites for academia or stakeholders.

In 2013 NP 216 scientists participated in research collaborations with scientists in: Brazil, China, Tunisia, Libya, India, Kuwait, Canada, and South Korea.

Accomplishments in FY 2013

This section summarizes significant and high impact research results that address specific components of the FY2008 – 2013 action plan for NP216. Many of the programs summarized for FY 2013 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA-ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs.

Component 1. Agronomic Crop Production Systems

Problem 1A. The value of U.S. crop output in 2002 was 2.6 times higher than that in 1948, while the total amounts of production inputs required to achieve this output have declined. However, the profitability of many farms producing major commodity crops is declining because of escalating costs of energy, fertilizers, and other purchased inputs. Strategies and technologies are needed to reduce production costs and risks of economic loss.

New geospatial databases assess crop and production patterns in the Northeast. Developing effective regional food systems has enormous potential to address health, nutrition, and poverty problems. In the Northeast, however, better management decision tools are needed to analyze current and future food production capacity in order to improve the access, affordability, and appropriateness of locally-produced food. ARS researchers from Orono, ME, in cooperation with the ARS in Beltsville, MD, developed a collection of geodatabases that provides county-level, five-year production footprints for key indicator crops (corn, potato, small grains, broccoli, cabbage, soybean, alfalfa, and 'other hay') throughout the entire 13-state northeast region. The databases bring together all available spatial information on cropping systems and crop production, soils, land use and quality, and water resources. These spatially-layered, user-friendly map products provide integrated information on past and present farmland extents and productivity. They are currently playing a key role in forecasting models to improve future farm and crop productivity.

Providing Safer fresh produce with sun-power (solarization)or cabbage leaves (biofumigation). Contamination of spinach and vegetables by *E. coli* and *Salmonella* has resulted in hundreds of cases of gastroenteritis, numerous cases of kidney failure, and even fatalities. The leafy greens industry has incurred millions of dollars of economic loss from reduced sales and settlements to victims. Preventing contamination of fresh produce is a critical crop protection strategy. Animal manure used as fertilizer or left by wildlife can contaminate vegetable crops with harmful bacteria. ARS scientists in Beltsville, MD, showed that covering soil with a clear plastic film (solarization,) and using biofumigation techniques (cabbage leaf incorporation into soil, 20 percent vinegar drench, or a commercially-available, organically-approved plant disease control soil drench) significantly reduced *E. coli* survival over a two week period. Non-treated soil and the white and black plastic reduced *E. coli* populations, but not as dramatically as the clear plastic film. These results can help all leafy greens producers, processors, and marketers reduce contamination of their crops and provide a healthy, safe food supply to the country.

Oat and rye cover crops substantially reduce nitrate losses in drainage water. Loss of nitrogen in groundwater from agricultural systems can increase nitrate in freshwater streams, which can lead to environmental problems such as hypoxia in the Gulf of Mexico, and economic problems such as more expensive drinking water treatment. Much of the nitrate in the Mississippi River comes from land used to produce corn and soybean, especially if it has been drained with subsurface drainage systems. Cover crops grown in the fall and winter can capture nitrogen that would otherwise be lost from fallow fields, and make the nitrogen available to the next year's crop. During a five-year period, ARS scientists at Ames, IA, showed that a cereal rye winter cover crop reduced the concentration of nitrate in drainage water by 48%, and an oat fall cover crop reduced nitrate concentrations by 26%. Both oat and rye cover crops are viable management options to keep nitrogen available to crops, which would decrease grower fertilizer costs for corn and soybean and reduce nitrate losses to the Mississippi River and the Gulf of Mexico.

Improving weed control and soil conservation in cotton fields Reduced, or conservation tillage can decrease labor and fuel costs, prevent soil compaction, increase water infiltration and soil water holding capacity, and reduce erosion. However, weed control under reduced tillage can be a challenge, especially in cotton production where pigweed has developed resistance to herbicides.. Cotton growers need information how well various strategies (such as high residue winter cover crops inversion tillage; and varying herbicide intensity, placement, and timing) are able to control herbicide resistant weeds. ARS scientists in Auburn, AL, demonstrated overall, systems that integrate high-residue cover crops, crop rotation, and variable herbicide strategies can improve pigweed control compared to high intensity tillage. Growers can capture the cost benefits of reduced tillage and improved cotton yields while also improving soil properties and reducing the environmental impacts of erosion.

Organic cropping provides ecosystems services that rival no-till cropping. Both organic farming and no-till cropping are proposed as alternative systems to increase sustainability of agricultural systems. However, ecosystem services between an organic system and a conventional no-till cropping system have not been compared. Using data from the long-term Farming Systems Project, ARS scientists in Beltsville, MD concluded that soil carbon storage and nitrogen fertility can be greater, while impact on climate change can be lower in organic systems that use animal manures and cover crops compared to conventional no-till systems that use conventional fertilizer and cover crops. Ecosystem services of organic systems are improved by expanding crop rotations to include greater crop diversity, using integrated nutrient management, and reducing tillage intensity and frequency. However, soil erosion and labor requirements are greater and crop yields are often lower in organic than no-till systems. These results are of interest to organic farmers, farmers considering transitioning to organic, and policymakers and others interested in increasing ecosystem services provided by all farming systems.

Healthier soil under strip tillage for sugarbeet. Strip tillage, which is a reduced tillage system where only the portion of the soil with the seed row is disturbed, can save producers up to $100 per acre from less fuel and labor costs. However, it is unclear if strip tillage leaves a soil too compacted for efficient sugarbeet production. ARS scientists in Sidney, MT, conducted a two-year study to evaluate soil compaction in sugarbeet fields under conventional and strip tillage. Measures of soil compaction were 39% greater under conventional tillage than strip tillage across all positions in sugarbeet rows and inter-rows, and in different soil depths. Results demonstrate that strip tillage can help farmers maintain better soil health and quality through improved soil water retention, soil infiltration, increased organic matter content, and reduced erosion, therefore helping to sustain crop yields with lower input costs.

Problem 1B. The United States has embarked on an ambitious program to replace a significant portion of petroleum-based transportation fuels with bio-based sources from agriculture. Producers, government agencies, energy companies, and policy makers need to know how to best produce energy crops in different agricultural regions of the country and what would be the likely impacts of energy production on whole-farm economic return and natural resource quality.

Mixed soil response to biochar reflects biochar heterogeneity. Biochar is a carbon rich by-product of gasification or pyrolysis (controlled heating of biomass without air to produce synthetic fuel). Biochar can be a valuable soil amendment to improve soil properties and sequester carbon, which helps reduce atmospheric greenhouse gasses. However, limited information is available on how biochar influences soil nitrogen and crop available nitrogen, yield response, and if all biochars behave in the same manner. ARS scientists in Beltsville, MD, in collaboration with the University of Georgia, found that biochar made from pecan shells, peanut hulls, and poultry litter increased nitrogen loss from soils. In contrast, ARS scientists at Corvallis, OR, discovered that incorporating biochar made from Kentucky bluegrass residues into a low-pH farm soil in eastern Washington resulting in a 1.5-fold wheat increase compared to untreated soil. The yield increase was attributed to improved soil water holding capacity, raised soil pH, and provided added mineral nutrition to the wheat crop when compared to lime-treated and untreated soils. These divergent responses demonstrate that while biochar can have economic, energy, and environmental value; it is necessary to match biochar to soil type and appropriate land use. These results provide information to producers and agricultural professionals seeking to optimize biochar benefits, promote greater sustainability of farm economics, soil health, and crop productivity, and simultaneously avoid unintended consequences.

Component 2. Specialty Crop Production Systems

Problem Statement 2A. High-value specialty crop production typically requires costly intensive practices to achieve profitable production of suitable market quality. Alternative management strategies are needed to reduce production costs but have neutral or positive impacts on yield, product quality, and risk of economic loss.

New combine technology increases profits for wheat growers. Some crops are sold under a quality payment system that rewards growers for maximizing the protein concentration of their grain. Conventional harvesting grain in one bin on a combine lessens the ability of growers to capture price premiums for high protein wheat. On-combine optical sensing creates an opportunity to segregate grain by protein concentration during harvest. ARS scientists in

Pendleton, OR, developed an on-combine system that uses a multispectral optical probe to automatically separate wheat by grain protein. Field tests showed it is possible to use grain protein to effectively separate grain into different bins on a combine without prior knowledge of harvesting zones. The scientists also developed the publically available "Grain Segregation Profit Calculator" software to calculate the cutoff value to use for segregating wheat into two lots so prices received for average protein levels in the lots are maximized. Dollar returns from grain segregation are sensitive to the average level of a field's protein, the protein variability within a field, and prices being paid in the marketplace. These technologies hold great promise for helping wheat producers increase their efficiencies and profits.

Weed management and genetic tolerance to plant population improves sweet corn productivity. Sweet corn is planted under a wide range of seeding rates and many newer hybrids are being planted at much higher rates than traditional cultivars. How these new hybrids respond to competition from both weeds and the high density of other corn plants is unknown. ARS scientists in Prosser, WA, and Urbana, IL, planted two sweet corn hybrids with different tolerance to weeds at five seeding rates both with and without wild proso millet as a weed. One corn hybrid consistently performed better against weeds, but neither hybrid was consistently more tolerant to other corn plants, with stress from weeds and corn being additive. The seeding rates that maximized yields and profits were between 28,300 and 35,700 plants per acre depending on location, and related gross profits ranged from $970 to $4300 per acre. The greatest profit occurred when yield and marketable properties, such as ear mass and number, were optimized. Weeds caused $800 to $3300 per acre profit loss. . This research shows that improving weed management and genetic tolerance to high plant populations can help farmers improve their sweet corn productivity and profits.

Genetic control of hairy vetch flowering time decoded. Winter cover crops are an important agricultural conservation tool to reduce soil erosion, prevent loss of nutrients during the winter, and improve soil organic matter and health. In no-till organic cropping systems, the onset of flowering indicates the earliest time a farmer can mechanically terminate cover crops without use of herbicides or tillage. Earlier-flowering cover crops are therefore desirable because of the ability to plant the next crop earlier in the spring. ARS scientists in Beltsville, MD identified genetic traits associated with significant variation in flowering time in the USDA hairy vetch collection. They identified five key flowering genes associated with initiation or inhibition of flowering and are regulated during transition from vegetative to flowering growth stages. Information on differences in the regulation of these genes can be used to rapidly identify hairy vetch varieties in future breeding programs with flowering times better synchronized with agronomic needs. This information can be used by crop breeders to improve the value of hairy vetch as a cover crop, and to promote the benefits associated with wider adoption of cover crops across the U.S.

Best practices determined for disease-suppressive rotation crops for potato. Previous research has identified *Brassica* and other disease-suppressive rotation crops that can substantially reduce soilborne diseases and increase yield in potato cropping systems. However, the most effective and practical ways to use and incorporate *Brassica* crops into potato production in the Northeast have not been established. In a series of experiments focused on determining which rotation crops are most effective, and how to implement and manage them (as cover, harvested, or green manure crops), ARS researchers in Orono, ME, determined that *Brassica* crops managed as green manures produced overall lower disease and higher potato yields than other practices. *Brassica* crops harvested for seed then incorporated also provided significant benefits, but *Brassica* managed strictly as cover crops were least effective. Mustard blend, sudangrass, and rapeseed all effectively reduced black scurf disease and increased potato yield. Overall, the combination of mustard blend managed as a green manure was most effective, reducing scurf by 54% and increasing potato yield by 26% relative to a soybean cover crop. However, due to the short growing season, *Brassica* crops were not effective when grown as fall-only cover crops. This research provides critical information needed by growers regarding the implementation of disease-suppressive rotation crops for enhanced productivity and reduced disease in potato systems.

Problem Statement 2B. Profitable alternative rotation crops are needed to enhance whole-system agroecological function, increase economic return, and reduce production risks. However, market barriers often exist when introducing new crops into existing systems due to lack of supply chain infrastructure and knowledge of consumer needs and market capacity.

Improved management can sustain malt yield and quality and increase soil organic matter. Traditional farming systems, such as conventional tillage with malt barley-fallow, have reduced annualized dryland malt barley yield and soil organic matter in the northern Great Plains. Improved management practices are needed to increase organic matter and improve barley yield and quality. ARS Scientists at Sidney, MT evaluated over five years the effects of tillage, cropping sequence, and nitrogen fertilization on malt barley yield and quality and soil carbon and nitrogen levels. Compared to a traditional conventional till and nitrogen fertilizer management, a no-till malt barley-pea rotation with half the nitrogen fertilizer increased mean malt barley grain yield and plump kernel by 16.8%, but reduced protein concentration by 2.8%. The alternative system also increased soil organic carbon, soil total nitrogen, and nitrogen balance. Using these more robust management techniques, farmers can reduce the rate and cost of nitrogen fertilization, sustain crop yield and quality, increase soil carbon sequestration and farm carbon credits, conserve nitrogen, and reduce the potential for nitrogen leaching, volatilization, and denitrification, which can help mitigate greenhouse gas emissions.

Perennial grass biomass is influenced more by grass species than by nitrogen fertilization. Production of biofuels as replacements for oil and gasoline continues to be pursued as issues of climate change, apparent declines in oil reserves, and insecure oil sources intensify. In the U.S., perennial grasses grown in dryland (non-irrigated) systems can potentially be used for cellulosic ethanol production, but there is often little agronomic information to guide producers who may choose to grow them. ARS researchers in Sidney, MT investigated the response of nitrogen fertilization on three grass species for biomass production. In wetter than normal years, intermediate wheatgrass yields were 25 to 50% greater than those for smooth brome and switchgrass, but in average rainfall years biomass yields were similar. The response of the grasses to nitrogen fertilizer was similar, and only during a wet year was a 20% increase in biomass observed at the greatest nitrogen rate (75 lb/ac) compared to the no-nitrogen control. Perennial grass biomass production in the Northern Great Plains is possible, but inconsistent response to nitrogen fertilizer and inconsistent yields associated with dryland climate could limit its use as a feedstock. These results will help inform potential growers as well as policy makers on the potential to produce biomass for alternative fuels in the U.S.

Component 3. Integrated Whole Farm Production Systems

Problem 3A. Whole-farm management approaches are lacking that take advantage of the complimentary benefits that could be produced by combining complimentary production enterprises. To assist farmers wishing to transition to more integrated whole-farm systems, research is needed to determine the relative amounts of risk of economic loss and potential trade-offs between economic and environmental outcomes for multiple-enterprise agroecosystems compared to specialized production systems.

Diverse agricultural systems are more complex, but more productive and stable. Greater demands for agriculture to provide food, feed, fiber, and fuel place increased pressure on farmers to intensify their production without compromising environmental quality. To improve the resilience of agricultural systems, ARS scientists at Mandan, ND, examined the role of biodiversity in the management of agricultural systems. Their research showed the use of a complex cropping system, such as different combinations of crops grown in different places depending on field conditions and producer goals, increased spring wheat yield up to 10 -20% and reduced yield variability compared to fixed crop rotations. Similarly, increasing diversity by integrating crops and livestock reduced bred cow overwintering costs by up to 32% compared to conventional haylot feeding. These new systems require new tools for management and for conducting trade-off analysis, so management may become more complex. These new systems can improve crop and animal productivity and consistency, while reducing risk by being more resilient to outside changes. They can also provide multiple ecosystem functions and increase the sustainably of agricultural systems.

Sheep grazing can sustain crop yields and increase soil carbon and nitrogen. In the Northern Great Plains, sheep grazing during fallow periods can be a cost-effective method of controlling weeds, diseases, and insects compared to more conventional herbicide application and tillage. However, little is known about the sustainability of grazing, and specifically the impact on soil fertility and crop production. ARS scientists at Sidney, MT, in collaboration with Montana State University, examined over two years the effects of sheep grazing compared to herbicide application and tillage on soil carbon and nitrogen and crop yields. Grazing increased soil organic carbon and total nitrogen, especially in a spring wheat-barley/pea mixture hay-fallow system, primarily from sheep consuming crop residues and weeds and returning carbon and nitrogen to soil in feces and urine. Sheep grazing did not influence yields and nitrogen uptake of spring wheat, pea/barley hay, and alfalfa. Farmers can use sheep grazing to maintain crop yields while increasing soil carbon and nitrogen, and reduce nitrogen loss through leaching, volatilization, and denitrification. These benefits have potential to reduce producer input costs and generate farm carbon credits, while promoting healthier soils and environment.

Component 4. Integrated Technology and Information to Increase Customer Problem-Solving Capacity

Problem Statement 4A. Researchers and stakeholders need methods to understand the best ways new production technologies and management systems should be delivered so producers can more easily adopt them.

No significant results reported in FY13.

Problem Statement 4B. There is need to determine the technical limits and feasibility of integrating new technologies to ensure that their use will increase agricultural efficiency and economic competitiveness.

Crop water stress factors quantified for limited irrigation systems. Dwindling water supply for irrigated crop production is the most limiting factor facing agriculture in the world today. Reliable estimation of plant response to irrigation is essential for model-based decision support tools to make the best use of limited water. ARS scientists in Ft. Collins, CO, conducted a four-year irrigation study of corn response to soil water content and evapotranspiration. They also updated the ARS crop system model RZWQM2 to more accurately simulate the soil energy balance components of net radiation, latent heat, sensible heat, and ground heat flux. The updated model also simulates crop canopy temperature, which is a plant water stress guide for timing water application that not found in other crop system models. Implementing the knowledge gained by these studies ARS scientist improved the reliability of RZWQM2 as an irrigation planning and scheduling tool. This research represents a unique and valuable combination of physical and model research for an irrigation planning and scheduling tool than can now be more reliably used to manage limited water resources in the U.S. and globally.

Problem Statement 4C. USDA-ARS long-term systems research experiments have produced extensive data sets for physical, chemical and biological indicators, but this information has not been available in accessible forms for use by other researchers, agencies, and non-traditional customers.

No significant results reported in FY13.

Problem Statement 4D. Integrated multiple-objective economic and environmental effects assessments are needed at varying scales for agricultural systems across the United States.

No significant results reported in FY13.