FY2012 DRAFT Annual Report
National Program 216- Agricultural System Competitiveness and Sustainability

Increasing demands are being placed on agriculture. Society expects a safe affordable supply of high quality nutritious food, a clean healthy environment, a growing economy that provides a comfortable standard of living for its citizens, and increased use of renewable sources of energy. These expectations are to be met 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 time period.

Agricultural production 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, 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; and an infrastructure that facilitates timely distribution and export of agricultural products. Similar advances will be needed in the future to meet societal demands.

Modern agriculture must confront a number of major challenges in the near future. The population of the United States and the world is growing rapidly and agricultural productivity will have to increase to meet future food and fiber needs. The percentage of the population that is involved in agricultural production is small and declining with a majority of people living in urban areas. These demographics have resulted in a large segment of the population being unfamiliar with what agriculture provides and how it is provided. Housing needs and the 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). In addition to space there is increasing competition for other resources essential to agriculture. In many regions of the country water supplies will likely not meet future demand. Agriculture is a major consumer of energy and expectations for increases in feedstock production for biofuels to reduce dependence on foreign energy are increasing. Finally, production agriculture will be required reduce emissions of greenhouse gases and sequester carbon to contribute to mitigating climate change and develop or shift practices to adapt to climate change.

The approach used in this National Program (NP216) is to conduct research that provides farmers with management practices, decision aides, and information needed to "move farming systems along a trajectory toward greater sustainability on each of the four goals". Specific research topics will 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. Projects in this National Program will contribute to a database and participate in regional and national efforts to synthesize results using assessment tools and process based models. The overall goal is to make production agriculture more sustainable.

NP216 is organized into four problem areas:

- Food, feed, fiber, and feedstock production systems
- Production system economics
- Production system effects on natural resources
- Integration of sustainability goals

ARS scientists identified research outcomes and products and the resources available to conduct the research for each problem area in this Action Plan. ARS scientists participating in NP216 will reference this Action Plan to develop project plans that describe the research they will conduct. These project plans contain detailed objectives, anticipated products and information generated, approach to be used, scientists and cooperators participating in the research, and a timeline and milestones to measure progress of the research. A summary of selected research accomplishments for FY2012 is given below.

ENHANCING THE YIELD OF FOOD, FEED, FIBER, AND FEEDSTOCK PRODUCTION SYSTEMS

This component addresses research problems in agricultural 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). The primary function of research in this component is on understanding the underlying agroecological principles for development of technologies and production strategies for producing the food, feed, fiber, and feedstock needed by society.

Selected Accomplishments

Cover crops may negatively influence vegetable germination. Cover crop residues often release allelochemicals that can reduce germination and seedling growth of other plant species, which can be part of the mechanism by which they help reduce weed pressure in cropping systems. These chemicals may also inhibit establishment of cash crops because they are not specifically targeted to weedy plants. Sunhemp is a tropical legume with significant potential for use as a cover crop in the southeast. Its residues suppress weeds, but their effects on cash crops are relatively unknown. ARS scientists from Beltsville, Maryland, in collaboration with University of Georgia scientists, evaluated the effects of sunhemp residues and cereal rye residues on weeds and vegetable crops in greenhouse and growth chamber experiments. In the greenhouse study, dried sunhemp residues and rye residues similarly suppressed germination of lettuce and smooth pigweed (a weed). Sunhemp leaf tissue had a greater effect than to root tissue. In a second study, water extracts of sunhemp leaves significantly inhibited germination of bell pepper, tomato, and onion, and suppressed turnip and okra germination by 50%, while germination of sicklepod, a common weed in southern cropping systems, was not affected by the extracts. In addition, sunhemp leaf extracts inhibited root elongation of lettuce, carrot, smooth pigweed and ryegrass. These results indicate that sunhemp residues can help reduce weed pressure, but field-scale evaluations are needed to assess subsequent crop germination under actual growing conditions.

Integrated crop-livestock systems maintain soil quality. Integrated crop-livestock systems, which combine crops and cattle, benefit farmers agronomically and economically. An

unanswered question, however, is how livestock influence soil quality for succeeding crops. ARS scientists at Mandan, North Dakota compared the soil quality of an integrated winter grazing management system with perennial grass pastures, which are considered the "gold standard" for soil quality. After nine years of detailed observation, the soil quality of the integrated winter grazing system equaled that of the perennial grass system on these northern Great Plains soils. This new information will benefit farmers in the northern Great Plains by assuring them that they can graze crop residue without a negative impact on soil quality

Long-term evaluation of cover crop biomass production and nitrogen accumulation in high-input, tillage-intensive production systems. Long-term research is needed to provide growers with reliable information on cover crop performance across years with variable winter climatic conditions. Cover crop biomass production and nitrogen accumulation were evaluated over eight winter periods in a rotational study with organic vegetables. ARS researchers in Salinas, California, found that rye and legume-rye produced 25 percent more cover crop biomass than mustard and that legume-rye accumulated 35 percent more nitrogen. This research provides growers with critical information to choose the most cost-effective cover crops to maximize organic matter inputs that can help maintain and improve soil quality and vegetable yields with minimal fertilizer inputs, and minimize nitrate leaching into ground and surface waters.

Biodiesel crops such as juncea canola are promising replacements for fallow in dryland durum rotations. Identifying suitable cropping alternatives to fallow can increase acreage for crops that can be used as biodiesel and jet fuel feedstock. These potential cropping systems need to efficiently use nitrogen (N) fertilizer, which is a major input expenditure. USDA researchers at Sidney, MT investigated N use and efficiency of three oilseeds as replacement for fallow in 2-year durum rotations. Results from the five-yr study suggested that in semi-arid areas, juncea canola could be a suitable alternative to fallow in 2 year durum rotations. Under the study, growing juncea canola in place of fallow did not affect the following year's durum yield meaning producers can expect to maintain existing profits from their wheat production while adding additional profit from a new cash crop. Because a significant number of fallowed acres are available in semi-arid regions, the nation could also benefit through an increased supply of oilseed feedstocks for biodiesel production which could help reduce our dependence on imported oil, without impacting existing food production.

New cropping system identified to mitigate greenhouse gas emissions while maintaining crop yield. Currently, agricultural activity accounts for an estimated six percent of greenhouse gas emissions (carbon dioxide, nitrous oxide and methane) contributing to global warming in USA. Information is needed on management practices that can help mitigate agricultural greenhouse gas emissions in the semiarid Northern Great Plains region which can be readily adopted by irrigated and dryland producers without the need for new equipment or technology. ARS scientists at Sidney, Montana evaluated the effects of tillage, crop rotation, N fertilization, and irrigation on soil greenhouse gas emissions from 2008 to 2011 under dryland and irrigated cropping systems. Their study identified a no-tilled malt barley – pea rotation with nitrogen fertilization between 0 and 80 kg N/ha as a promising rotation option for producers in the region. Results suggest that a no-tilled malt barley-pea rotation with reduced rate of nitrogen fertilization could be used as a management option to mitigate greenhouse gas emissions, while still sustaining malt barley yield, and quality. Farmers thus may practice good environmental

stewardship by adopting a no-tilled malt barley- pea rotation in either dryland or irrigated farmland.

Weed control for conservation tillage. Weed control in conservation tillage is currently under attack due to troublesome herbicide resistant weeds. Rotating herbicide modes of action is an important resistant management tool. Unfortunately, lack of alternative herbicide modes of action included in glyphosate resistant cotton herbicide systems continues. Thus, a field experiment was conducted by ARS scientists in Auburn, Alabama in cooperation with Auburn University to evaluate integrating high residue cover crops, alternative row spacings, and conventional, glyphosate and glufosinate cotton systems. The glufosinate and glyphosate weed management systems controlled at least 97% of large crabgrass, Palmer amaranth, sicklepod, and smallflower morningglory, while the conventional system controlled 89, 73, and 87 to 98% of large crabgrass, smallflower morningglory, and Palmer amaranth, respectively. In this study, the glyphosate weed management system resulted in higher cotton yield than the conventional and glufosinate systems. Cotton yield response to tillage system varied among years, with conservation tillage yielding more than conventional tillage during a dry year.

ENHANCING PRODUCTION SYSTEM ECONOMICS VIABILITY

This component addresses research problems on the profitability of agricultural production systems. The primary function of research in this component is on understanding the economic factors affecting production system profitability and developing strategies for profitable food, feed, fiber, and feedstock production.

Selected Accomplishments

Assessing food cropping and production patterns in the Northeast with new geodatabases. Development of effective regional food systems holds much potential for improving health, nutrition, and economic well-being. But before progress can be made towards improving the access, affordability, and appropriateness of locally-produced food in the Northeast, better tools are needed to analyze and assess current and future food production capacity within the region. In cooperation with a team of University researchers and ARS researchers from Beltsville, Maryland, ARS scientists in Orono, Maine developed a 13-state collection of geodatabases that brings together available spatial information on cropping systems and crop production, soils, land use and quality, and water resources throughout the entire region. These mapping products provide integrated information on past and present farmland extents and productivity and are being used with forecasting models for improving future farm and crop productivity. Through integration of multiple layers of useful data in these geodatabases, this work will be used to help improve the access and affordability of locally-produced food for the northeast region.

Cover crop biomass production and nitrogen accumulation in high-input, tillage-intensive production systems. Growers need reliable information on cover crop performance over years with different winter conditions. ARS researchers in Salinas, California, evaluated cover crop biomass production and nitrogen accumulation over eight winters in a rotational study with organic vegetables. Rye and a legume-rye mix rotation produced 25 percent more cover crop

biomass than mustard and the legume-rye mix accumulated 35 percent more nitrogen. This research provides growers with critical information to choose the most cost-effective cover crops to maximize organic matter inputs that can help maintain and improve soil quality and vegetable yields with minimal fertilizer inputs, and minimize nitrate leaching into ground and surface waters.

Conservation tillage can benefit sugarbeet farmers. As input costs for fuel, fertilizer and labor continue to increase, producer profits are being squeezed. Sidney, Montana ARS scientists have shown that new management techniques can help reduce those costs. For example, ARS scientists have verified that tillage practices affect soil-water-plant ecosystems and can impact soil properties, plant growth, crop yield and quality of sugarbeets. A 4-year study of three tillage practices was conducted on a sandy loam soil in western North Dakota to determine whether conservation tillage practices, including no-till, impacted sugarbeet yields. Under the study, tillage had no significant effect on sugarbeet root and total sucrose yields, which means sugarbeet farmers can lower their input costs (energy, fuel, labor and time) by using conservation tillage thereby reducing cropping costs and increasing profitability. In addition, conservation tillage can help farmers maintain better soil health and quality (through improved soil water retention, soil infiltration, increased organic matter content, and reduced erosion), contributing to more sustainable or even increased crop yields in the future.

Powered rolling and crimping device developed for small farms. In small vegetable/organic systems, bigger tractors are not used because they are too expensive, heavy, and large for small planting areas. Instead, 2-wheel walk-behind tractors and small implements are utilized widely, but there were no small rollers/crimpers available to effectively crimp and terminate cover crops without herbicides (as required in organic systems). An effective, low weight roller/crimper compatible with 2-wheel tractors was needed. An ARS scientist from the National Soil Dynamics Laboratory in Auburn, Alabama, developed a unique powered roller/crimper for self-propelled walk-behind tractors that allows growers with small farms to successfully terminate and manage cover crops without commercial herbicides. The development of this patented powered roller/crimper is important for small no-till organic vegetable systems, where commercial herbicides are banned, and traditional rollers are too heavy for limited power 2-wheel tractors and too large for narrow beds typical of smaller farms in the USA and worldwide.

Gasification char has utility as a soil amendment. The effects of char produced from gasification of Kentucky bluegrass residues on plant productivity when used as a soil amendment, and consequently, its utility as a value-added product was unknown. ARS researchers at Corvallis, Oregon, conducted greenhouse trials which proved that when used as a soil amendment, the char increased soil pH, reduced the uptake of aluminum by wheat plants, and improved biomass production. Chemical analyses of the char also demonstrated that returning char to the production fields sequestered significant quantities of carbon and returned potassium and phosphate to the soil. This accomplishment showed that char produced by on-farm gasification has economic and agronomic value as a soil amendment and will enhance the economic feasibility of on-farm gasification of agricultural residues.

Maintaining sugarbeet, malt barley and potato yields with lower input costs. The impact of irrigation frequency on yields and producer profitability has not been fully explored in sandy soils in semi-arid regions. Successful irrigation management is one of the most important

agronomic practices for achieving profitable yield and maximizing crop water productivity (CWP) while maintaining environmental quality by minimizing water losses to runoff and deep drainage. ARS scientists at Sidney, Montana completed a seven year study comparing irrigation frequency on crop water use (CWU) and CWP in sugarbeet, malt barley and potatoes under self-propelled automated sprinkler systems. No significant differences in yields, CWU, or CWP for sugarbeet (root and sucrose), malt barley or potatoes due to irrigation frequency were found on sandy loam soils. Thus, conventional low frequency irrigation can sustain yields as well as high frequency irrigation practices. Incorporation of this practice can improve water use, and reduce leaching and input costs for farmers using self-propelled automated sprinkler systems on sandy soils.

Crop residue supply for bioenergy. Crop residues, materials remaining in the field after grain harvest, are a promising abundant source of biomass for bioenergy production. However, it is important that harvesting crop residues does not harm the environment and is economically feasible for both farmers and biorefiners. ARS researchers at Mandan, North Dakota and Morris, Minnesota developed a method to determine the prices and amounts of biomass that could be profitably supplied to a local biorefinery. This technique identifies specific fields where biomass prices will be profitable. Results for a Minnesota biorefinery showed that farmers could begin to profitably deliver corn stover at prices above $53 per ton, and that transportation costs result in crop residue harvest being concentrated near the biorefinery, concentrating environmental impacts near the facility, as well. These results provide farmers and biomass industry with information and an analytical method needed to evaluate the economic viability of using crop residues for energy production while avoiding negative environmental impacts.

Sunn hemp as a nitrogen (N) source for winter cover crops. Sunn hemp is a tropical legume that produces plant biomass and nitrogen quickly, but seed is very hard to obtain and expensive, if available. ARS scientists in Auburn, Alabama, in cooperation with Auburn University examined the agronomic performance of a new sunn hemp cultivar, across different planting dates and seeding rates, breed to produce seed in the Southeast and determine how much N is available to a subsequent rye winter cover crop following corn and wheat harvests. Sunn hemp biomass production was inconsistent but did relate to the growing season. Neither planting date nor seeding rate affected rye biomass production, but rye biomass averaged over both planting dates following wheat/sunn hemp averaged 43% and 33% greater than rye following fallow. Rye biomass following corn/sunn hemp was equivalent to fallow plots, which was related to the shorter growing season. This research indicates early planting dates are recommended for sunn hemp with seeding rates between 17 and 34 kg/ha to maximize biomass and subsequent N production as a N source for winter cover crops in the Southeast.

PRODUCTION SYSTEM EFFECTS ON NATURAL RESOURCES

This component addresses research problems on the soil, water, and air resources associated with production systems. The primary function of research in this component is to understand the physical, chemical, and biological processes in production systems and develop strategies for meeting air, water, and soil quality expectations of society.

Selected Accomplishments

Sheep grazing can help lower agricultural greenhouse gas emissions. ARS scientists from Sidney, Montana collaborated with scientists from Montana State University to show that using sheep to control weeds during fallow periods of crop rotations may also reduce greenhouse gas emissions. Currently, agriculture contributes about 6% of the United States' greenhouse gas emissions. A two-year study showed that sheep grazing has little impact on greenhouse gas emissions compared to the herbicide method of weed control under dryland cropping systems, while still maintaining crop yield and quality. Less intensive sheep grazing with reduced nitrogen fertilization rates can be used to mitigate greenhouse gas emissions and sustain crop yields. Consequently, both animal and crop producers may benefit from sheep grazing during fallow as an effective and potentially inexpensive method of weed control that not only can sustain crop yields, but also mitigate greenhouse gas emissions.

Emissions of a greenhouse gas may be reduced by up to 50% in the central and eastern U.S. While agricultural soils are the dominant source of nitrous oxide (N_2O), a greenhouse gas and catalyst of stratospheric ozone decay, we have a very limited understanding of the impact of various management practices on N_2O emissions. ARS scientists from Beltsville, Maryland and Ames, Iowa summarized recent research findings from the central and eastern U.S to show that reducing N fertilizer application rate to an economic optimum, reducing the proportion of high nitrogen demanding crops within a rotation, and possibly long-term no-tillage could reduce N_2O emissions by up to 50% in the central and eastern U.S. There is insufficient and/or inconsistent evidence indicating whether other proposed N_2O mitigation strategies—nitrogen fertilizer and manure timing, placement or source selection, nitrification inhibitors, delayed release fertilizers, or cover crops—provide any mitigation. Results show that substantial additional research is needed to provide policymakers with recommendations about best management practices to reduce soil N_2O and CH_4 emissions from cropland soils.

Greenhouse gas emissions from soil amended with anaerobic digested dairy manure. Dairy production in the Pacific Northwest has grown steadily over the past decade resulting in large concentrations of animal wastes. These wastes have been implicated in the decline of surface and subsurface water quality as well as an increase in the production of greenhouse gases when used as a soil amendment. Field studies by scientists in Prosser, Washington showed that emission rates of GHG were significantly less (60%) than the emission value proposed by the International Panel on Climate Change (IPCC).

Fairy rings found to enhance soil structure and boost western wheatgrass production. Stimulation of plant productivity in fairy rings caused by the fungus Agaricus lilaceps has been reported, but little is known about factors aiding that productivity, particularly with respect to production of western wheatgrass, a desirable native forage. In collaboration with the Bureau of Land Management, Sidney, Montana scientists studied soils and plants in three concentric sampling zones (outside the ring, inside the ring and the ring itself) caused by fairy rings in eastern Montana rangeland. ARS scientists found that the activity of the basideomycete fungi associated with the actual fairy ring, versus the zones in or outside the ring, was primarily responsible for enhancing soil quality and influencing beneficial bacterial communities that together stimulated growth of the desired western wheatgrass within the ring. Consequently, encouraging the growth of fairy rings could increase forage availability in Montana rangelands.

Biological soil quality tool evaluated. Soil quality is an essential feature of sustainable agricultural systems, as many important ecosystem services (e.g. nutrient cycling, water cycling, climate regulation, etc.) are functionally derived from well-working soil properties and processes. The biological component of soil quality has been difficult to assess due to its highly dynamic nature and diversity of processes controlled by soil microorganisms. A group of scientists from Michigan State University, Pennsylvania State University, Ohio State University, Cornell University, University of New Hampshire, University of California, University of Illinois, U.S. Agency for International Development, and ARS in Beltsville, Maryland and Watkinsville, Georgia collected soils from 12 studies at 53 sites to evaluate the potential of using a simple, rapid, biochemical method (permanganate oxidizable carbon) as a biological soil quality tool. The biological soil quality tool was highly related to other more process-oriented and methodologically-sophisticated biological evaluation measures. In fact, this simple biological soil quality tool was sometimes more effective in discriminating among different soil treatments. The rigorous and widespread evaluation across a diversity of soils suggests that this simple, rapid, and inexpensive biochemical method can be widely used to evaluate management-induced changes in biological soil quality. This has important implications for assessing the impacts of land restoration and management for maintaining and improving ecosystem services derived from the world's soils.

INTEGRATION OF SUSTAINABILITY GOALS

This component addresses research problems that must be overcome to synthesize the data so that sustainability at the farm/regional/or larger scales can be assessed. This synthesis is necessary to insure that progress is being made in all sustainability goals as we work to move farming systems along a trajectory toward greater sustainability. The primary function of research in this component is to develop a database, develop analytical tools for processing datasets, and use or develop statistical methods, assessment tools, and models to synthesize results and compare systems at various scales.

Selected Accomplishments

Oat and rye cover crops substantially reduce nitrate losses in drainage water. Much of the nitrate in the Mississippi River comes from land used to produce corn and soybean. Cover crops grown between maturity and planting of these crops are one approach for reducing losses of nitrate. ARS scientists in Ames, Iowa, showed that a rye winter cover crop reduced the concentration of nitrate in drainage water by 48% over five years. The oat fall cover crop reduced nitrate concentrations by 26%. Both oat and rye cover crops are viable management options for reducing nitrate losses to the Mississippi River from land used for corn and soybean production.

GPS-guided drill operation captures runoff on steep slopes. Contour farming has long been recommended as a means of retaining water on hill slopes and preventing soil erosion. A geospatial positioning system method was developed and validated by scientists in Pendleton, Oregon to guide a tractor and its seed drill along the elevation contour lines on a hill slope.

Results demonstrated that seeding precisely in one pass on the elevation contour of an upper shoulder slope can effectively capture and hold the runoff from a 100-year, 24-hour storm event. Using terrain map information and GPS-based autosteering systems, contour seeding promises to improve soil and water conservation in many tillage systems. The method can be implemented using commercially available mapping software and autosteering equipment designed for tractors and drills.

In-line NIRS technology for in-stream measurement of canola seed oil concentration. Natural variation in the seed oil concentration of oilseed crops sent to a crushing plant can impair the recovery of oil from the seed. Scientists in Pendleton, Oregon, demonstrated that the in-line NIRS technology can determine seed oil concentration in a grain stream to within an error of 0.73%. This result is sufficiently promising to suggest that in-line NIRS could be used to evaluate the performance of the extraction process in a crushing plant so that the expeller can be adjusted to maximize oil extraction and minimize residual oil levels in the finished meal. Ability of crushing plants to monitor extraction efficiency would also enhance profitability and help ensure maximum efficiency of the harvested acres of oilseed crops.

GPS-guided drill operation captures runoff on steep slopes. Contour farming has long been recommended as a means of retaining water on hill slopes and preventing soil erosion. A novel method was developed and validated by scientists in Pendleton, Oregon to guide a tractor and its seed drill along the elevation contour lines on a hill slope. Results demonstrated that seeding precisely in one pass on the elevation contour of an upper shoulder slope can effectively capture and hold the runoff from a 100-year, 24-hour storm event. Using terrain map information and GPS-based autosteering systems, contour seeding promises to improve soil and water conservation in many tillage systems. The method can be implemented using commercially available mapping software and autosteering equipment designed for tractors and drills.

Agriculture conservation practices increase amphibian habitat accessibility. Agricultural ecosystems are potential habitat for amphibians in areas where historical aquatic breeding habitats and upland hibernacula (shelter of hibernating animal) have been lost and can also act as barriers to amphibian movement between aquatic breeding habitats and upland overwintering hibernacula. Conservation efforts such as crop residue management practices, riparian buffers (inhabiting or situated on the bank of a river), and reduced tillage practices have the potential to mitigate the impacts of agriculture on local species by improving habitat quality and connectivity in agriculturally dominated systems. ARS researchers at Corvallis, Oregon, analyzed the effect of field level conservation efforts employed in the Calapooia watershed, (Central Willamette Valley) in Oregon, on amphibian species diversity at multiple spatial scales. There was a positive association between amphibian species diversity and the percentage of land in a conservation practice at the sub-basin scale, but not at smaller spatial scales (e.g., 150, 250, 500, and 1,000 meter buffer zones from the breeding sites). This study suggested that conservation practices implemented on grass seed cropping systems increase habitat connectivity for local amphibian species, allowing for greater species diversity at aquatic breeding sites in these agricultural landscapes.

Crop water production functions (CWPFs) for Colorado. The CWPFs estimate crop yields at different levels of irrigation, which can be used by producers to decide the most economical level

of irrigation to apply for a selected crop. ARS researchers at the Agricultural Systems Research Unit in Fort Collins, Colorado used the previously validated cropping system model (Root Zone Water Quality Model) with long-term weather data to develop average CWPFs for corn, wheat, and dry beans for three soil types in six different counties of Colorado. The modeled CWPFs for drip irrigation were also extended to sprinkler and surface irrigation methods. These functions are being put into the ARS 'Colorado Water Optimizer' decision tool and provided to a Cooperative Research and Development Agreement (CRADA) partner. Producers use these data to optimize use of limited water for different crops.

A rangeland drought management tool. The western U.S. rangelands are increasingly facing droughts, and rangeland managers need a simple predictive drought management tool to adjust the size of grazing herds. ARS researchers in Fort Collins Colorado, in collaboration with the USDA Risk Management Agency developed a 'Drought Calculator' (DC) tool based on the relationship between forage growth and rainfalls during the winter and spring months. Based on the initial results, the DC has been developed for use in10 states and is available from the ARS AgSoftware website.

Categorical fusion of elevation and imagery information. An analysis methodology was developed by ARS scientists at Mississippi State, Mississippi, in cooperation with scientists at Mississippi State University that combines two maps, the digital elevation model (DEM) of field elevation relief and the arctangent of the Normalized Difference Vegetation Index (NDVI), into a single map which categorically describes the phenological variability of the crop. This map can be used to direct scouts to different regions of the field to assess insect pests or evaluate other crop conditions. The map can be used to improve the timing of various management decisions or to prepare the prescription for a variable-rate application. Other impacts are (1) the expansion of understanding of spatial autocorrelation structures of agricultural fields; (2) the development of additional processing methods for remote sensing products if a third geographical layer is available; (3) a better understanding of temporal changes that arise to the crop within and between seasons; and (4) leads to better analyses of factors that affect agricultural production to reduce cost and manage risk.