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NATIONAL PROGRAM - 216
AGRICULTURAL SYSTEM COMPETITIVENESS AND SUSTAINABILITY

American farms generate more than $200 billion in goods and services on 442 million acres. Profitable farms are also the basis of vibrant rural economies. Consumers benefit from agricultural production that provides an abundant choice of products at relatively low costs. However, many farms are suffering from commodity prices that have remained relatively unchanged for decades, while the costs of fuel and other purchased inputs continue to rise. In addition, there is increasing competition from overseas markets where production costs are comparatively low. At the same time, continued advancement of conservation goals is needed to enhance the natural resource base upon which the nation not only depends for food, feed, fiber, and renewable energy, but also for abundant and high quality supplies of fresh water, clean air, and healthy ecosystems. The challenges producers face regarding productivity, profitability, and natural resource stewardship are complex, so solutions to these challenges are equally complex.

The USDA-ARS projects contributing to National Program *Agricultural System Competitiveness and Sustainability* (NP 216) use an interdisciplinary systems research approach to bring together the diverse expertise needed to understand how different kinds and sizes of farms function, and how changing or introducing new technology will affect their economic and environmental sustainability. Whether the ARS teams of scientists and their university and industry cooperators are in the Pacific Northwest, Southwest, Great Plains, Midwest, Southeast, or New England, they use their collective scientific talent to find the best combinations of practices to help producers achieve their production goals.

NP 216 *Agricultural System Competitiveness and Sustainability* contributes to USDA-ARS Strategic Plan Goal 2: Enhance the Competitiveness and Sustainability of Rural and Farm Economies, Objective 2.1: Expand domestic market opportunities, and Objective 2.2: Increase the efficiency of domestic agricultural production and marketing systems; and Strategic Plan Goal 6: Protect and Enhance the Nation’s Natural Resource Base and Environment.

AGRONOMIC CROP PRODUCTION SYSTEMS

The ***Agronomic Crop Production Systems*** component addresses challenges in agricultural systems dominated by the commodities including corn, soybean, cotton, peanut, wheat, barley, and turf and herbage seed crops. The value of U.S. crop output in 2002 was 2.6 times higher than that in 1948, while the 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. Research is needed to develop production strategies and technologies that increase productivity and reduce production costs and risks of economic loss, all while maintaining or even enhancing natural resource quality.

In addition, the United States has embarked on an ambitious program to replace a significant portion of petroleum-based transportation fuels with bio-based fuels from agricultural sources. Producers, government agencies, energy companies, and policy makers need to know how best to produce biomass and dedicated energy crops in different agricultural regions of the country and what the likely impacts would be of an expanding bio-economy on whole-farm economic return and natural resource quality. A new generation of production systems and technologies is needed to produce feedstocks sustainably to support emerging bioeconomies in ways that do not disrupt the integrity of existing farms and markets or degrade the quality of natural resources.

Montana Dryland Cereal Producers Can Increase Profits by Considering Reduced Tillage and Optimal Cropping Sequences. Scientists at the Northern Plains Agricultural Research Laboratory in Sidney, Montana have reported results from a 21-year study of the effects of tillage method and cropping sequence for cereal production. Even though less wheat was produced each year with the annual crop system, total income over the two years was greater than for one crop produced every other year. Mean crop biomass was 53 to 66% greater with reduced tillage with an annual cropping system than for conventional till with a spring wheat followed by a fallow system. During a six-year drought period during this long-term study, zero-tillage management allowed greater soil water to be available at planting than with conventional tillage. Just as importantly, the amounts of carbon and nitrogen in the soil surface residues were 23 to 141% greater than in the conventional tillage system. These findings demonstrate both the yield and conservation benefits of using reduced tillage practices in the Northern Great Plains region, and provide the scientific basis to support participation in USDA Farm Bill Conservation Title programs.

Using Cover Crops Enhances Conservation Management Benefits. Cover crops provide the additional carbon needed to gain the full benefits from using conservation cropping systems in most regions. Successful adoption of cover crop use in conservation tillage systems requires knowledge of establishment methods, types of cover crop, fertilizer management, and termination equipment. USDA-ARS scientists from the National Soil Dynamics Laboratory in Auburn, Alabama and the J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, Georgia, in conjunction with other regional experts synthesized diverse information on managing cover crops in conservation systems to produce a comprehensive guideline titled *Managing Cover Crops Profitably*. Both general recommendations, as well as specific considerations for different regions of the United States are presented. The compiled information is being adopted by university extension agents in training programs to help producers incorporate cover crops into farm operations and USDA-NRCS to develop conservation plans for delivery of Farm Bill Conservation Title programs in the Southeastern region.

Autumn-Applied Nitrogen Fertilizer is Needed for Optimal Winter Grass Cover Crop Growth. Scientists at the National Soil Dynamics Laboratory in Auburn, Alabama previously showed that to maximize winter cover crop biomass, supplemental sources of nitrogen are needed. However, it was not know whether residues from summer-grown peanuts could supply a portion of the nitrogen requirements for these winter cover crops.

This study assessed the nitrogen contribution of peanut residue to a rye winter cover crop in a conservation management system. Peanut residues did not enhance cereal rye biomass yields, but additional autumn-applied nitrogen increased the amounts of cereal rye biomass produced. Although growers should still be encouraged to leave peanut residue in the field, recommended nitrogen rates for winter annual grass cover crops should not be reduced. This kind of practical information is needed so growers can make science-based decisions when looking for the best nutrient management options for their farms in the Southeastern Coastal Plains region.

Barriers Identified That Keep Midwestern Growers from Using Cover Crops. Even as the benefits of cover crops continue to be reported, it is not known how many farmers are actually using cover crops, and what keeps more from doing so. ARS scientists at the National Soil Tilth Laboratory in Ames, Iowa are working with collaborators at Iowa State University to find out how many farmers in the Corn Belt use cover crops in their production systems. It was found that farmers who grow a greater diversity of crops were more likely to use cover crops, but only 18 percent of farmers in the region reported ever using cover crops — only 8 percent had planted cover crops in the fall of 2005. Eighty percent of farmers use some other sort of conservation practices, and indicated that they believed that cover crops improve soil conditions by reducing erosion and increasing soil organic matter. However, over a quarter of farmers perceived that cover crops are too expensive to use, and over a third believed that planting cover crops took too much time. These findings will help researchers design their work to demonstrate the maximum combined benefits from using cover crops to Midwest farmers and help them realize ways to maximize profits.

Conservation Tillage Offers Significant Water Savings for Southeastern Region. The long-running water rights negotiations among Alabama, Florida and Georgia focus on diminishing water resources, but ignore the potential water savings offered by conservation tillage adoption in the region. USDA-ARS research scientists from the Southeast Watershed Research Unit in Tifton, Georgia and J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, Georgia used county-level crop, tillage, and soil information to show that conservation tillage currently reduces agricultural irrigation water requirements by as much as 12%. Increasing conservation tillage to 40% in counties where conservation tillage adoption rates were below the 41% national average increased water savings 10% statewide which is equivalent to 13.7 billion gallons – the equivalent local savings of 0.2 to 6.0 years of water use. These findings provide guidance for policy makers to help resolve the needs for water and manage its use by agriculture and urban populations in the Southeastern U.S.

Integrated Conservation Management Practices Combined with Subsoiling Not Only Mitigate Compaction, But Also Reduce Fuel Use. Compaction limits the productivity of most Southern United States soils, so farmers typically use periodic in-row subsoiling to loosen compacted soil layers to promote root growth and increase crop yields. However, the cost of this operation has become increasingly expensive with rapidly escalating fuel prices. USDA-ARS scientists at the National Soil Dynamics Laboratory in Auburn, Alabama have shown that fuel use can be reduced 54% when subsoiling by proper selection of bentleg subsoiler shanks used at shallow tillage depth, operating at the proper soil moisture condition, using cover crops, and controlling vehicle traffic. An additional benefit was minimal disruption on the soil surface of the crop residues that help intercept precipitation and prevent soil erosion. All of these practices in combination are an integrated approach for conservation management in Southeastern mixed crop production systems.

Integrating Cover Crops with Conservation Tillage Practices Can Reduce Cotton Production Costs. Scientists from the J. Phil Campbell, Sr., Natural Resource Conservation Center, in Watkinsville, Georgia along with cooperators from the University of Georgia and Monsanto Inc. compared seven kinds of cover crops for use in cotton production on a Coastal Plain soil with strip tillage and no-till conservation practices. The legumes hairy vetch and Austrian winter pea fixed about half the amount of nitrogen needed to grow a cotton crop, while the combination of black oat and strip-tillage provided an additional $20 to $30 per acre returns than a cereal rye cover crop alone. Using nitrogen fixing cover crops to replace purchased nitrogen adds to the savings from conservation tillage practices, and enhances soil quality that contributes to increased crop productivity. Combined, these practices can increase returns to Coastal Plain producers where a majority of the 2.9-million acres of cotton in the southeastern U.S. is grown.

Conservation Tillage Can Increase the Economic Sustainability of Mississippi Delta Cotton Production Systems. Concern about increasing costs of production and the need to protect soil and water resources has led many Mississippi Delta cotton producers to consider various conservation practices, including reduced tillage and cover crops. However, the economic impacts of these practices are not known. USDA-ARS scientists at the Application and Production Technology Research Unit in Stoneville, Mississippi in collaboration with Mississippi State University scientists and producers demonstrated that the highest returns and lowest relative risks on Delta alluvial soils would be obtained by using a traditional no-till production system. Additional use of cover crops or sub-soiling as a part of the management package increased yield sufficiently to offset the additional expenses associated with these practices. Conventional production practices, while giving relatively high returns, were also the riskiest compared to conservation tillage management. These results are of particular importance in designing more economically and environmentally sustainable cotton production systems for the Mid-South region where growers are highly dependent upon USDA Farm Bill programs for financial success.

No-till Irrigated Corn May Yield Less with No-till Establishment, but Economic Returns are Greater than with Conventional Tillage. Conversion of irrigated conventional tilled cropland to no-tillage establishment could provide a number of environmental benefits, but the economics of production are not known. Scientists at the Northern Great Plains Research Laboratory in Mandan, North Dakota and the Soil Plant Research Unit in Fort Collins, Colorado investigated costs and returns for conventional tillage and no-till irrigated continuous corn production in Northeastern Colorado. Even though corn yields were lower under no-till than under conventional tillage, production costs were reduced so much that profits were greater for the no-till establishment system. This research provides farmers with economic analysis information that is needed to assure them that yield losses due to switching to no-tillage irrigated corn production will be offset by greater profits. Adoption of a no-tillage conservation management system should also lead to reduced soil erosion and fuel consumption, increased soil carbon sequestration, and lowered greenhouse gas emissions.

No Evidence Found of "Tough *Bt*" Corn Residues. There is widespread anecdotal information within the agricultural community that residues from some genetically modified (GM) corn hybrids may be resistant to degradation. As a result, implement manufacturers are now marketing alternative tillage machinery to deal specifically with "tough *Bt*" corn residue. USDA-ARS scientists at the North Central Agricultural Research Laboratory in Bookings, South Dakota evaluated the field decomposition rates of residues from *Bt* and non-*Bt* corn hybrids over a period of 22 months. No differences in the decomposition rates of the chopped residue from the four corn hybrids were detected. Additional studies are underway to determine alternate explanations for the perceived toughness of *Bt*-containing corn residues. Widespread adoption of un-necessary aggressive tillage would offset decades of gains in soil and water quality improvement that has been achieved through conservation tillage practices. This research is critical with greater amounts of corn being planted to meet the increasing demand for fuel ethanol.

Critical Soil Biology Functions Impacted by Genetically Modified (GM) Soybean Production. Genetically modified Roundup-resistant™ soybeans are planted on over 90% of soybean acreage in the U.S. However, a full assessment of the impacts of this technology on whole systems has not been conducted. Scientists at the Cropping Systems and Water Management Research Unit in Columbia, Missouri have determined the effects of GM Roundup-resistant soybean treated with Roundup herbicide on crop residue decomposition and soil biological processes under variable soil moisture conditions. Most of the measurements, including decomposition, showed no effect from Roundup or GM soybean at any soil moisture. However, the *Fusarium* fungal group consistently infected soybean roots at a higher incidence at all soil moisture levels in fields receiving Roundup, than with no Roundup applied. Results indicate that general biological measures such as residue decomposition did not detect GM soybean effects, but *Fusarium* microbial groups were more sensitive indicators of effects. This information is important because it helps to understand the occasional production problems observed in production system using GM soybeans, and to develop management solutions that will avoid crop growth reductions when GM soybean are included as a part of the management package.

Sustainable Straw Amounts Available for Biofuel Production are Estimated for the Pacific Northwest. Straw produced during cereal and grass seed production in Oregon, Washington, and Idaho represents a potentially significant feedstock, but the amount and location of straw in excess of that required for conservation purposes was not known. Scientists at the USDA-ARS Forage Seed and Cereal Research Unit in Corvallis, Oregon determined total straw production for all counties in these three states and determined county-by-county amounts of straw that should be returned to the soil for conservation purposes. A geographic information systems resource map was developed showing where the 7 million tons of straw that are annually produced in the region can be harvested. This information is useful to farmers and biofuel-producing companies who are beginning to consider the best strategies for utilizing this resource, and to government agencies for developing the best policies to ensure that high quality soil and water resources are maintained.

Nutrient Replacement Needs Determined for Irrigated Switchgrass Production in the Inland Pacific Northwest. Perennial herbaceous bioenergy crops have the potential to sequester soil carbon, supply a portion of U.S. energy needs, and reduce atmospheric CO_2 enrichment when used as a fuel. Scientists at the USDA-ARS Vegetable and Forage Crop Research Unit in Prosser, Washington have determined the amounts of essential plant nutrients that will be exported from farms with harvested biomass to determine reductions in soil fertility and how these will impact fertilizer recommendations for irrigated farms in the Inland Pacific Northwest. Harvested switchgrass biomass yields averaged 22 metric tons per hectare per year, and would produce 7,500 liters of ethanol. For every dry ton of switchgrass harvested, 25 lbs of nitrogen, 3.2 lbs of phosphorus, and 27.1 lbs of potassium are removed from the field. Bioenergy crop producers can use this information to adjust fertilization rates to meet their feedstock production goals and to ensure that adequate nutrients are available for subsequent crops grown in rotation. In addition, these data can be used in the development of secondary markets, such as carbon credit trading or by ethanol producers interested in nutrient recovery for production of fertilizer or animal feed supplements.

SPECIALTY CROP AND ORGANIC PRODUCTION SYSTEMS

The ***Specialty Crop and Organic Production Systems*** component is focused on solving problems related to the production of high-value specialty crop and value-added organic products. The value of U.S. specialty crops is greater than the combined value of corn, soybean, wheat, cotton, and rice crops. At the same time, organic production now captures more than 3% of the U.S. food market, and is growing at a rate of 10% annually. The production of high-value specialty and organic crops often requires cost-intensive practices to achieve profitable production levels of products that must be of sufficient quality to meet high market and consumer preference standards. Producers wishing to produce high-value specialty and organic crops may face significant barriers to the development and marketing of new products. Alternative management strategies are needed that utilize an understanding of the agro-ecological and biophysical processes innate to plants, soils, invertebrates, and microbes that naturally regulate pest problems and soil fertility, to reduce or replace reliance on the use of synthetic pesticide and fertilizer production inputs. Also, an understanding of marketing supply chains from field-to-table must be considered and integrated with production, handling, and processing information to increase the portion of product value received by producers.

Brassica Green Manure Crops Reduce Soilborne Potato Diseases. Soilborne diseases are persistent, recurring problems in potato production and are difficult to control, resulting in reduced plant growth, tuber quality, and yield. Brassica rotation crops and green manures have the potential to control multiple soilborne diseases through biofumigation and changes in soil microbial communities. USDA-ARS scientists at the New England Plant, Soil, and Water Laboratory in Orono, Maine conducted on-farm field trials and showed that mustard, canola, and rapeseed green manures reduced powdery scab by 15-40%, and canola and rapeseed reduced black scurf by 70-80%. A mustard green manure also reduced common scab by 25%. Overall, mustard was most effective in reducing powdery and common scab diseases, and rapeseed and canola were most effective in reducing *Rhizoctonia* diseases. This research provides conventional potato growers with a viable tool for reducing soilborne disease levels without additional pesticides, and is useful to organic producers who do not use synthetic fungicides.

Cover Cropping Practices Improve Organic Weed Management. USDA-ARS scientists at the Crop Improvement and Protection Research Unit in Salinas, California, along with university and grower cooperators, showed that different cover crops produce similar amounts of biomass, but there are large differences in their weed suppressive abilities. At typical seeding rates, weed suppression was excellent by mustard and rye, but extremely poor in legume/cereal mixes. Increasing the seeding rate of the legume/cereal mixes improved weed suppression to acceptable levels. Also, rotary hoe use can reduce weed seed production in winter cover crops by up to 80%, so weeds are less of a problem in the spring.

Purple Bounty Hairy Vetch Variety Released for Cover Crop Use. USDA-ARS scientists in the Sustainable Agriculture Systems Laboratory at Beltsville, Maryland in cooperation with Pennsylvania State University, the Rodale Institute, and Cornell University, released Purple Bounty, a new hairy vetch cultivar that combines the traits of early flowering and improved winter survival. Hairy vetch is planted in the fall and, after over-wintering, produces abundant biologically fixed nitrogen in the spring that can be used to nourish subsequent crops such as corn and tomatoes. The early flowering feature of Purple Bounty is an important advantage because it permits earlier planting of the subsequent crops. The availability of Purple Bounty should encourage more widespread use of this nitrogen-fixing legume cover crop. The initial large-scale seed increase of Purple Bounty was made at Meadville, Pennsylvania.

Fresh-Market Onion Production is Aided by Cover Crops. Lack of soil organic matter in hot, arid climates limits agricultural production and sustainability. To enhance soil organic matter, scientists at the Kika de la Garza Subtropical Agricultural Research Center in Weslaco, Texas have used a combination of cowpea and sorghum cover crops to increase soil organic matter by 52% and 61%. As a result, yields were increased 60-80% and there was an increase in the percentage of large market onions. Also, increasing soil organic matter improved soil tilth so that it was easier for the onions to be mechanically transplanted, with less need for follow-up labor. This achievement is important because it demonstrates that improved soil quality can also be translated into increased onion yield and quality. These findings are useful to both conventional as well as organic farmers.

Bulletin Released Describing Sustainable Production of Fresh-Market Tomatoes and Other Vegetables. USDA-ARS scientists in the Sustainable Agricultural Systems Laboratory at Beltsville, Maryland released U.S. Department of Agriculture, Agricultural Research Service, Farmers' Bulletin 2280 that focuses on the winter annual legume hairy vetch, both as a cover crop and mulch in a sustainable tomato production system. As a cover, vetch serves to fix nitrogen, recycle nutrients, reduce soil erosion and compaction, and add organic matter to the soil. When converted to mulch, the residue reduces weed emergence, reduces water loss from the soil, acts as a slow-release fertilizer, and suppresses some pathogens and pests. Though research on this mode of production was originally confined to growing tomatoes in stands of hairy vetch, further study has shown that the underlying concept can be easily modified to suit other crops and regional growing conditions. Some direct-seeded vegetables can be grown effectively, as can winter vegetables in subtropical climates. Other cover crops can be selected and even seeded in beneficial mixtures to suit local growing conditions.

Limited Sweet Corn Yields Need to be Overcome When Using Legume Cover Crops. Legume cover crops can substitute for and reduce fertilizer nitrogen inputs in different cropping systems. A three-year field experiment was conducted by USDA-ARS scientists in the Sustainable Agricultural Systems Laboratory at Beltsville, Maryland to measure the nitrogen released from a hairy vetch cover crop and the efficiency with which this nitrogen was used in sweet corn production compared to nitrogen supplied in fertilizer. Fewer marketable ears were produced by sweet corn grown on nitrogen released from a decomposing hairy vetch cover crop than by corn grown on synthetic nitrogen released from fertilizer. The lower crop use efficiency of nitrogen derived from hairy vetch cover crops is caused by reduced crop population as a result of interference by heavy levels of surface cover crop residue. This research shows the need to find new ways to manage legume cover crops to overcome limitations to organic sweet corn productivity.

White Plastic Barriers for Blackberry Weed Control Provide Multiple Benefits. Weed pests are a challenge to control in blackberry brambles, particularly when organic methods are employed. USDA-ARS researchers at the Integrated Farming and Natural Resources Research Unit, Weslaco, Texas found that white plastic weed barriers used to control weeds in newly planted brambles not only reduced labor needed for weed control, but improved blackberry yields and fruit quality. Improved plant vigor and berry soluble solids likely result from more consistent soil temperatures at four inches, while maintaining consistent soil moisture amounts.

Weed Control Costs Reduced for Organic Vegetable Producers. Hand labor for weed management in high-value organic vegetable crops can cost up to $1500 per acre. USDA-ARS scientist at the Crop Improvement and Protection Research Unit in Salinas, California and cooperators conducted on-farm research to evaluate the effectiveness and costs of six organic weed management tools to prepare stale seed beds in high-density vegetable production. These techniques included organic herbicides, propane flamers, and various cultivation tools. Most techniques controlled more than 70% of the weeds and cost less than $230 per acre. However, the organic herbicide was ineffective and cost

$1557 per acre. These findings identified effective methods to help organic producers minimize the need for hand weeding of high value vegetable crops.

Combining Biological Amendments with Cultural Practices Improves Potato Disease Control and Productivity. Potatoes frequently suffer from numerous soilborne diseases that reduce tuber quality and yield. Biological amendments, including biocontrol organisms, microbial inoculants, and compost teas, may be used to increase soil microbial diversity and antagonism towards soilborne pathogens. In multi-year field trials, USDA-ARS scientists at the New England Plant, Soil, and Water Laboratory in Orono, Maine showed that a combination of conifer-based compost and biocontrol amendments resulted in significant reductions in *Rhizoctonia* disease (23-48%) and improved tuber yield (30-50%). Combining biological amendments with an effective crop rotation (barley underseeded with ryegrass) reduced stem canker, black scurf, and common scab by 18-33% and increased potato yields by 20-32%. This research shows that combining biological and cultural practices can substantially reduce diseases and increase yields without additional use of synthetic pesticides.

Potato Late Blight Infection Comes from a Common Weed. Potato Late Blight caused by *Phytophthora infestans* is a serious worldwide threat to the potato and tomato industries. USDA-ARS scientists at the New England Plant, Soil, and Water Laboratory in Orono, Maine previously reported the first identification in Maine of *P. infestans* on the common weed hairy nightshade. In 2007, the scientists further evaluated the significance of hairy nightshade as an alternate host to potato Late Blight, and found that disease severity varied with source of inoculum (9-37%), weed sage-of-growth (6-21%), ambient temperature (1-14%), and relative humidity (6-18%). Results from this ecological-based pest management research shows that potato growers can reduce their risk of potential Late Blight infection by controlling hairy nightshade weed populations, and reduces the need for fungicide applications.

Potato Root-knot Nematode Resistant Genetic Lines Negated by Hairy Nightshade. Columbia root-knot nematode is a major pest of potato in the Pacific Northwest and is controlled by costly soil fumigation. Nematode-resistant potato breeding lines developed by USDA-ARS scientists in the Vegetable and Forage Crop Research Unit at Prosser, Washington were shown to segregate in response to nematode damage on tubers when grown in the presence hairy nightshade. Some lines possessed only root resistance and lacked tuber resistance, while other lines possessed both root and tuber resistance. These findings demonstrate how weed hosts of root-knot nematodes may negate the positive impact of growing resistant potatoes that lack tuber resistance and the importance of weed control on managing plant parasitic nematode populations. Commercial potato breeders can use this new information to select for both root and tuber resistance in breeding materials.

Feasibility of Organic Grain Production Systems Improved. There is inadequate information regarding the performance of organically produced grain crops in the United States, especially in Coastal Plain soils of the mid-Atlantic region. USDA-ARS scientists at the Sustainable Agricultural Systems Laboratory in Beltsville, Maryland showed in a ten-year study that average corn yields in organic systems increase with increasing crop rotation length and increasing diversity of crops grown in rotations. Average corn grain yield was 30% greater in a corn-soybean-wheat-hay rotation than in a corn-soybean rotation, and 10% greater than in a corn-soybean-wheat rotation. Differences were due to increased nitrogen availability and lowered weed competition with increasing crop rotation length. This research shows that increasing crop rotation length and complexity can address the two most important production challenges in organic grain crop production: providing adequate nitrogen for crop growth and decreasing weed competition.

Organic Grain Production Transition Strategies for the Northern Corn Belt Region. While many environmental benefits are realized from reduced tillage, increasing crop diversity, and reducing agricultural chemical use, short-term economic factors often encourage farmers to use intensive tillage, high amounts of chemical inputs, and specialized crop production. Scientists at the North Central Soil Conservation Research Laboratory in Morris, Minnesota compared crop yields and economic costs and returns for northern Corn Belt farmers who desire to switch from a conventional corn-soybean cropping systems to a range of alternative systems including organic production. Results from the research showed that increasing crop diversity and reducing tillage intensity generally reduced production costs. Yields were reduced under organic production conditions compared to conventional systems, but when considering the overall production system costs, many crops under alternative management showed no significant differences in net returns, suggesting that there were no economic barriers to adopting these practices. Economic returns for most organic systems were comparable or exceeded those from conventional production when organic price premiums were included. This research provides farmers with information needed to help them decide whether to switch to more profitable alternative production systems that include reduced tillage intensity, increased crop diversity, and organic production. This research will also be an important source of information for policy makers in determining economic incentives that may be necessary to encourage producers to adopt these practices.

INTEGRATED TECHNOLOGY AND INFORMATION SYSTEMS

The ***Integrated Technology and Information Systems*** component focuses on research to develop and apply technologies that can be used to understand and increase production system economic and environmental sustainability. ARS customers want not only the latest information and best technology research can provide, but also to know how these innovations can best be incorporated into their unique operations. Also important to know is whether the use of new technology will increase farmer ability to compete in the marketplace or to deliver their services. Understanding the system level impacts of implementing new technologies will help increase adoption and reduce uncertainty and risk. Recognizing that users are the ultimate system integrators, customer participation in the entire research process becomes a necessity for the successful transfer and adoption of emerging technologies.

"Trigger-on" Indicator for use with Precision Weed Sensing Sprayer Units. A major drawback with precision intermittent application spray systems that only spray when weeds are present is that no feedback is provided to the operator when each spray unit is activated. This limitation makes it difficult to determine if the sensors are functioning properly, particularly on wide boom spray units. To overcome this problem, the Columbia Plateau Conservation Research Center, Pendleton, Oregon developed a low cost trigger-on indicator that provides visual feedback to the operator. The device performed reliably over a 150-hour test period. This development will help speed the adoption of herbicide-reducing intermittent spray systems on large-acreage farms.

A Wireless Sensor-based Site-specific Irrigation Solution. To save water resources and minimize agrichemical leaching to groundwater, a sensor-based site-specific irrigation approach was developed by the Northern Plains Agricultural Research Laboratory at Sidney, Montana This approach incorporates an in-field wireless sensor network and variable-rate irrigation control for on-farm use. Sprinkler nozzles can now be controlled wirelessly by a real-time information feedback of the soil-water status of the crop. This technology allows growers remote access to field conditions, and real-time control of site-specific irrigation technology can help ensure that the correct amount of water is applied at the right time, thus reducing the risk of crop loss and inefficient water use with associated energy usage.

New Sensor Offers Accurate Way to Estimate Crop Residue Cover for Conservation Management Compliance. Accurate and rapid methods for determining tillage and crop residue cover are limited at the field and watershed scale but are needed for assessing Conservation Program qualification and compliance. Scientists at the Southeast Watershed Research Unit, Tifton, Georgia and J. Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, Georgia, found that a handheld multispectral radiometer sensor could be used to detect tillage and residue cover differences on Coastal Plain and Piedmont region soils as well as currently used time consuming line-transect estimates. Residue cover indices that were developed to differentiate between conservation and conventional tillage could be valuable tools for USDA-NRCS and other agencies to make rapid watershed-scale assessments of conservation tillage adoption.

Spatial Analysis-of-Covariance Method Uses Farmer Precision Agriculture Information. USDA-ARS scientists at the Genetics and Precision Agriculture Research Unit in Mississippi State, Mississippi have developed an improved way to analyze whole field experiments using real-time on-farm data that are collected by farmers. Three data set applications of the methodology were utilized: (1) the effect of herbicide drift on corn growth and yield as related to the topography co-variates of imagery and elevation; (2) the response of nematode treatment strategies as related to topography co-variates of imagery and VERIS soil conductivity data; and (3) the use of ARS methodology used by a cooperator in Louisiana to determine the effects of variable-rate nitrogen applications in tandem with variable-rate nematode control. In all three applications, the custom ERDAS Imagine application built cooperatively with Leica was tested and extensively used in these spatial co-variate analyses for the first time. This custom application is able to generate polygons of different widths and lengths according to polylines of travel followed by commercial application equipment. This ERDAS Imagine application was also provided for individual use by cooperators at Mississippi State, Stoneville Experiment Station, and the Louisiana State University Experiment Station at St. Joseph, Louisiana.

Tolerances Determined for Optimal Benefits from Automatic Steering to Control Equipment Traffic. Producers in the southeastern Coastal Plains region use strip tillage prior to planting in order to manage soil compaction in conservation tillage systems. USDA-ARS scientists from the National Soil Dynamics Laboratory in Auburn, Alabama determined how automated steering controls could be used to improve the accuracy of deep tillage and planting operations in high-residue conservation tillage systems. Results showed that if deep tillage was two inches away from the planting row, cotton yields were reduced by 24-52% with net revenues reduced 38-83%. Because of the costs of the technology, larger farms are most likely to benefit from highly accurate automatic steering systems, while smaller farms may need to use cheaper alternatives, such as foam markers placed over strip-tilled rows.

Strip Tillage Technology Developed for Sugarbeets. Three years of research by USDA-ARS scientists at the Northern Plains Agricultural Research Laboratory in Sidney, Montana have shown that strip tillage on sprinkler-irrigated sugarbeets leads to substantial fuel savings by greatly reducing the number of tractor passes required to establish the crops, compared to conventional tillage practices. Also as a result of strip-tillage, the percentage sucrose in the beets was consistently higher with equivalent yields as conventional tillage. This work is has been well received by growers in the MonDak region of the Northern Great Plains, who have adopted the practice on 5000 acres in 2007 (up more than 400% from 2006).

Precision Nitrogen Applications Could Reduce Nitrogen Fertilizer Use in the Pacific Northwest. Current wheat management strategies in the Pacific Northwest largely ignore spatial and temporal interactions between the crop and environment. USDA-ARS scientists in the Land Management and Water Conservation Research Unit at Pullman, Washington tested the effectiveness of geographical information system referenced information to assess the efficacy of precision nitrogen management on wheat performance and economic returns. Precision applications reduced nitrogen (N) fertilizer use by up to 20% compared to uniform N management, without negatively impacting grain yield or protein content. In addition to reducing the costs of nitrogen fertilizers, the undesirable consequences of agricultural chemical movement from the field could be reduced.

Improved Wheat Yields and Quality Achieved with Variable Application Rate Technology. As input costs increase, producers throughout the U.S. are seeking ways to maintain crop yield and quality while decreasing production cost. The Integrated Cropping Systems Research Unit in Brookings, South Dakota utilized variable-rate technology that is currently in use in the southern Great Plains to apply variable rates of nitrogen fertilizer based upon in-season winter wheat plant nitrogen needs. The average amount of nitrogen needed to obtain maximum yield and quality decreased significantly over traditional soil test nitrogen recommendations, potentially reducing the impact of nitrogen fertilizer losses from fields to water sources, and decreasing overall production costs in the Northern Great Plains region.

Wheat Nitrogen Status Index Developed Based on Remotely Sensed Information. Exhaustive field sampling needed to acquire broad-scale information on in-season crop nitrogen status is constrained by high cost and lack of time. USDA-ARS scientists at the Columbia Plateau Conservation Research Center in Pendleton, Oregon investigated how remote sensing could be used to rapidly map crop nitrogen deficiencies across entire wheat fields in the Inland Pacific Northwest region. Ground reference measurements of crop canopy reflectance were converted to the band equivalent reflectance of the RapidEye™ satellite series. Using this information, a new vegetation index was developed from the red-edge band that is highly correlated with leaf chlorophyll and nitrogen contents. This new approach overcame the limitations of conventional indices, which are confounded by crop growth variation caused by differences in plant available soil water. The novel index enables prediction of nitrogen status across wheat fields and can be used to make decisions about fertilizer nitrogen management at mid-season without having to rely upon costly ground sampling methods. Combining this new technology with variable application rate methods will help make precision application of fertilizer nitrogen a reality.

Sensors on Combines Used to Provide Real-Time Estimates of Grain Quality. The advent of near infrared (NIR) on-combine sensors gives growers the opportunity to measure and map the grain protein concentration of wheat during harvest across farm fields. Scientists at the Columbia Plateau Conservation Research Center in Pendleton, Oregon used an in-line NIR sensor on a grain harvest combine to measure the protein concentration of soft white wheat within 0.5% accuracy. This finding supports the use of on-combine sensing during harvesting to segregate grain based on protein concentration, thus enabling growers to better capture price premiums in value-added markets that pay premiums for quality.

CERES-Maize Model Estimates Best Strategies for Corn Produced under Limited Water Conditions. USDA-ARS scientists at Agricultural Systems Research Unit in Fort Collins, Colorado validated the CERES-maize model for dryland and irrigated corn production conditions at Akron, Colorado and evaluated production responses to different levels of limited irrigation over 92 years of historical weather records. The study found that 20% of limited water application during vegetative stage and 80% during reproductive stage of corn was the best recipe to save water with no effect on yield. This study provides evidence that a system model can help develop location-specific agronomic practices to maximize water use efficiency under limited water conditions. Concepts developed in the study will be adapted to other locations, climates, and crops.

Corn and Soybean Field-scale Responses to Soil Water Availability Interpreted. USDA-ARS scientists at the National Soil Tilth Laboratory in Ames, Iowa used many years of observations across many corn and soybean fields in central Iowa to reveal seasonal patterns of soil moisture variation that are related to the stress dynamics of crops through out the growing season. Reflectance patterns based on hyperspectral wavelengths from 0.4 to 1.2 μm were based on bare soil patterns within the field. In average rainfall years, the variation across the fields during April through June was minimal at the time of maximum vegetative development. Soil water was not a limitation to growth, except in years with excessive rainfall in low areas of fields that caused water-logging and crop death. When rainfall was below 60% of normal, water deficits occurred in low water-holding capacity soils. With these findings, it was determined that excess rather than limited rainfall was typical for central Iowa. Spatial variation increased during the grain-filling period because the evaporation rate of the crop increased and the rainfall amounts decreased, making the crop depend on stored soil water within the field. Spatial patterns of stress in early August are related to final yield maps collected at harvest. Comparison of various vegetative indices related to biomass, leaf area, or plant senescence rate all exhibited the same pattern during the growing season. Soil moisture spatial patterns within fields outweighed the patterns induced by nitrogen management or planting rates. Efforts to decrease variation within fields will have to focus on methods of increasing soil water availability to offset water stress late in the growing season.

Satellite Imaging Used to Identify Crops in Field Across a Landscape. Landscape scale knowledge of crop production is necessary to understand how different production practices impact natural resource quality, but collecting such information from the ground is expensive and time consuming. USDA-ARS scientists in the Forage Seed and Cereal Research Unit in Corvallis, Oregon applied existing satellite image technology to identify crops produced for every field within a western Oregon watershed and the tillage practices used to establish these crops. Information derived from these images enabled participating scientists to establish water quality monitoring studies to quantify the effect of tillage practices on the amount of nitrogen in ground and surface waters. This novel application of satellite imagery to landscape land use analysis has provided a relatively inexpensive approach to correlate land use practices, including tillage of agricultural fields, with water quality and wildlife habitat.

Electrochemical Sensing for Precision Management of Soil Macronutrients. Soil sample collection and analysis is costly and time-consuming when applied at the intensity needed for variable-rate fertilizer management systems. Scientists at the Cropping System and Water Management Research Unit in Columbia, Missouri have developed an efficient approach to sensing soil macronutrient status of crops as a machine moves across a field. Soil nitrate, phosphate, and potassium ion-selective electrode (ISE) sensors were used with Kelowna multiple-element extracting solution to accurately quantify nutrient levels in laboratory solutions. With proper calibration procedures, the ISE sensors can accurately measure nutrient levels in typical agricultural soils. The combination of sensors and the associated extracting solution could be incorporated into an overall nutrient sensing system that could be used to reduce fertilizer application through precision application management.

New Decision Making Capacities Using the MAIZSIM Corn Simulation Model. Integrated multiple-objective economic and environmental effects assessments are needed at varying scales for agricultural systems across the United States. USDA-ARS scientists in the Crops Systems and Global Change Laboratory at Beltsville, Maryland have completed a new mechanistic corn simulation model named MAIZSIM. Previously, there were no comprehensive mechanistic corn models that simulated the plant processes using biologically based light interception, photosynthesis processes, and carbon partitioning. MAIZSIM will be an important management and assessment tool for agricultural managers, scientists, and policy makers who desire to consider different strategies to increase corn production under existing or changing climate conditions.

Improved Accuracy Built into the SPUDSIM Potato Simulation Model. USDA-ARS scientists in the Crops Systems and Global Change Laboratory at Beltsville, Maryland have improved the accuracy of the SPUDSIM potato model to simulate canopy light absorption and photosynthesis. State-of-the-art advances in our knowledge of light attenuation and gas exchange processes within the crop canopy are not incorporated in a majority of existing potato models. The accuracy of SPUDSIM predictions has been improved by incorporating process-level information on leaf gas exchange response to the light environment. Mathematical expressions for leaf appearance, duration, and expansion were also incorporated into SPUDSIM. The modifications were validated with independent data. These additions improve the usefulness of the model for policy decision makers and growers to evaluate the effects of management decisions on potato production.

Model Approach Evaluating the Effectiveness of Cover Crops Used to Reduce Nitrate Leaching in Tile Drainage Systems. Including winter cover crops such as winter rye in corn-soybean rotations is one of the more promising practices to reduce nitrate loss from tile drainage systems without negatively affecting production. USDA-ARS scientists at the Agricultural Systems Research Unit in Fort Collins, Colorado have tested the RZWQM-DSSAT hybrid model for simulating the effects of cover crop versus no cover crop on nitrate leaching losses in subsurface drainage water. Field experimental data collected over several years from Boone County, Iowa were used to calibrate the model. Average observed and RZWQM-simulated flow-weighted annual nitrate concentrations (FWANC) in subsurface drainage water for the cover crop treatments were reduced 61% and 50%, respectively, for actual measured and model-simulated waters from tile drainages. This modeling approach can help farmers and conservation planners determine the best places to use cover crops to achieve desired reductions in nitrate losses from fields.

Autocalibrated Version of the Soil Water Assessment Tool (SWAT) Model Applied to National Weather Service Flood Predictions. New technology has improved the kinds of weather data available to be used to increase the precision of flood predictions in the United States. However, appropriate models need to be identified that can utilize those data and accurately predict flood conditions. USDA-ARS researchers at the Forage Seed and Cereal Research Unit in Corvallis, Oregon have developed an automated method to calibrate the SWAT mode which was developed by the scientists at the Grassland Soil and Water Research Laboratory in Temple, Texas. The robustness of the autocalibration routine was demonstrated in a nationwide competition sponsored by the

National Weather Service where the USDA-ARS team was able to rapidly estimate the hydrology of five test watersheds using hourly radar data. The USDA-ARS team results compared very well with observed data, validated the use of SWAT, and provided a calibrated model that can be used as a flood prediction guide for the National Weather Service.