Accomplishments Report
(2008-2011)
National Program 216:
Agricultural System Competitiveness and Sustainability

Agricultural Research Service
U.S. Department of Agriculture

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Introduction

Purpose of this Report

This report summarizes selected accomplishments of the Agricultural Research Service's national program focusing on Agricultural System Competiveness and Sustainability. A key purpose of the report is to provide information for an external assessment of the program's performance over the past 4 years. This assessment will also provide recommendations for the future direction of the program. Because of space limitations not all of the program accomplishments can be presented. Emphasis is placed on reporting accomplishments that when taken as a whole will provide the greatest benefits to the public and scientific community.

Overview of the ARS Mission, Structure and Research Planning

The Role of the ARS. The Agricultural Research Service (ARS) is the principal **in-house research agency** of the U.S. Department of Agriculture (USDA). It is one of the four component agencies of the Research, Education, and Economics (REE) mission area. Congress first authorized Federally-supported agricultural research in the Organic Act of 1862, which established what is now the USDA. That statute directed the Commissioner of Agriculture "... To acquire and preserve in his Department all information he can obtain by means of books and correspondence and by practical and scientific experiments..." The scope of USDA's agricultural research programs has been expanded and extended many times since the Department was first created.

Interaction with National Institute of Food and Agriculture (NIFA). NIFA is also in the REE mission area and has responsibility for advancing scientific knowledge to help sustain the U.S. agricultural sector through a research, education and outreach system **external to USDA** by working with eligible partner institutions and organizations. The interrelated and complementary programs of ARS and NIFA requires these agencies to be visionary and forward thinking in effectively utilizing limited public resources through effective collaborative partnerships. Therefore, the two agencies regularly seek opportunities to increase the efficiencies of cooperative strategies and activities involving partnerships with the land-grant colleges and universities, other non-land-grant universities, Federal and State agencies and customers.

ARS size and budget. Today, ARS's workforce is approximately 9,000 employees, including 2,000 scientists representing a wide range of disciplines. ARS has approximately 900 research projects spread over 100 locations across the country and at 4 overseas laboratories. The National Agricultural Library and the National Arboretum are also part of ARS. The annual budget is just over $1 billion.

Mission objectives entering the 21st Century. ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provides information access and dissemination to

- Ensure high-quality, safe food and other agricultural products,
- Assess the nutritional needs of Americans,
- Sustain a competitive agricultural economy,

• Enhance the natural resource base and the environment, and
• Provide economic opportunities for rural citizens, communities, and society as a whole.

A problem-solving organization. To achieve these broad objectives, ARS identifies critical problems affecting American agriculture; develops strategies to mobilize resources (both human and financial); writes and reviews research plans to solve these problems efficiently; performs multi-disciplinary research; and reports the results to the customers. Each step of the process involves communicating and interacting with the scientific community, customers, stakeholders, partners, and beneficiaries to ensure program relevancy, quality and impact.

National programs. ARS research currently organized into 18 National Programs. These programs are managed by the Office of National Programs (ONP) through 30 National Program Leaders (NPLs) to bring coordination, communication and empowerment to the approximately 900 research projects carried out by ARS. The National Programs focus on ensuring the relevance, impact, and quality of ARS research. The national programs as currently structured are:

Animal Production & Protection
Food Animal Production
Animal Health
Veterinary, Medical, and Urban Entomology
Aquaculture

Natural Resources & Sustainable Agricultural Systems
Water Availability & Watershed Management
Climate Change, Soils and Emissions
Pasture, Forage & Rangeland Systems
Agricultural & Industrial Byproducts
Agricultural System Competitiveness & Sustainability
Bioenergy

Crop Production & Protection
Plant, Microbial & Insect Germplasm Conservation & Development
Plant Diseases
Crop Protection & Quarantine
Crop Production
Methyl Bromide Alternatives

Nutrition and Food Safety
Human Nutrition
Food Safety (animal & plant products)
New Uses, Quality & Marketability of Plant & Animal Products

Teamwork between national programs. Ideally, the entire ARS research portfolio would go through an integrated programming cycle, but this is not possible because of diversity, size and geographical distribution of agency's activities. The national program structure is an administrative construct dividing a complex research program into manageable parts. There are clearly overlaps between national programs and this is addressed by managing each national program with a National Program Team (NPT) of NPLs that provide the appropriate mix of skills and experience.

Introduction to the National Program Management and Cycle. The management of all ARS research programs is organized around a five-year National Program Cycle, consisting of four sequential phases (Input, Planning, Implementation, and Assessment) designed to ensure the relevance, quality, and impact of every ARS National Program. National Program Leaders (NPLs), working through multi-disciplinary National Program (NP) teams, define and articulate the scope of each program with input from customers, stakeholders, partners, ARS scientists, Areas, and the Administration. A prime mechanism used by the NP team to seek input is the NP workshop, conducted at the start of each program cycle. NPLs define the ARS program and provide broad scientific direction to ARS scientists through the development of the National Program (NP) Strategic Vision and the Action Plan. The Action Plans serve as the central reference for defining the program‘s relevance and performance expectations, as well as the basis for NPLs to assign research objectives, personnel, and dollars to units in the field. After programs are planned, research is implemented at ARS‘100+ locations across the Nation and the world. NPLs monitor and demonstrate performance at the program level through program annual reports, and have an ongoing coordination role. ARS continually monitors the quality of its work to meet Federal requirements and ensure public accountability. ARS regularly identifies accomplishments and major technology transfers in Project Annual Reports and NP Annual Reports. Also, toward the completion of every 5-year program cycle, each National Program‘s performance is evaluated by an external panel of customers and stakeholders against the goals and outcomes of the NP Action Plan.

Overview: Agricultural System Competitiveness and Sustainability (NP216)

Vision

Problem-solving research that helps producers and other users develop integrated solutions to solve their challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

Background

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 abundant choices of products at relatively low costs. However, many farms are suffering from commodity prices that until recently have remained relatively unchanged for decades, while the costs of fuel and other purchased inputs have continued 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 not simple.

The 18 projects in USDA-ARS National Program *Agricultural System Competitiveness and Sustainability* (NP216, Appendix A) use a similar interdisciplinary systems research approach to bring together the expertise needed to understand how different kinds of farms function and how changing or introducing new technology will affect their productivity, profitability, energy efficiency, and natural resource stewardship. Whether the ARS teams of scientists and universities 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 for different farming systems to help producers achieve their production goals. NP216 is one of six ARS National Programs in *Natural Resources and Sustainable Agricultural Systems* that conduct research at 70 locations comprising a nation-wide network dedicated to helping farms and ranches become more profitable while enhancing the environmental goods and services derived from agricultural lands.

Contribution to ARS Strategic Goals

NP216 Agricultural System Competitiveness and Sustainability contributes towards USDA-ARS Strategic Plan Goal 2: *Enhance the competitiveness and sustainability of rural and farm economies* Objective 2.2: *Increase the efficiency of domestic agricultural production and marketing systems,* and Objective 2.1: *Expand domestic market opportunities*; and Strategic Plan Goal 6: *Protect and Enhance the Nation’s Natural Resource Base and Environment*.

Approach
Participants at many of the USDA-ARS Customer Workshops have expressed their desire for holistic solutions to the problems they face on their farms. Not only do they want the best production methods, improved varieties, and advanced technologies research can provide, they want to know how these innovations can be best incorporated into their operations and whether their investment will increase their ability to compete in the market. Though many of kinds of problems producers face are the same across the country, it is accepted that every farm is different, so there are no "one-size-fits-all" solutions.

All locations and projects in this National Program conduct systems-level research to provide integrated solutions that enhance productivity, profitability, energy efficiency, and natural resource stewardship of different kinds and sizes of American farms. To gain a deeper understanding of the complexity of factors that affect the ways farms function, NP216 research projects require collaborations among teams of scientists with backgrounds in biological and physical science, ecology, economics and sociology, engineering, mathematics and modeling, and computer science. This interdisciplinary approach often requires partnerships with university, other state and federal agencies, and industry cooperators to bring additional talent as needed to solve the complex problems producers face.

Agricultural System Competitiveness and Sustainability research focuses on six approaches to address whole-farm competitiveness and sustainability:

- Identify new configurations of practices that utilize on-farm resources and natural ecosystem processes to reduce the need for purchased inputs and thus reduce whole-system costs and risks.
- Develop precision management, automation, and decision support technologies to increase production efficiencies, reduce costs, and limit adverse impacts or even enhance natural resources quality.
- Develop strategies for incorporating sustainable bio-based energy production into existing farm enterprises to increase income diversity and contribute to whole-farm energy self-sufficiency.
- Incorporate consumer preference and supply chain economic information to expand market opportunities and demonstrate how producers can respond to changing markets and increase economic returns.
- Provide scientific knowledge and analyses to inform policymakers seeking solutions to increase agricultural profitability, efficiency, and competitiveness.
- Use industry, Federal, State, and local partnerships to identify and solve problems, convey research results and information transfer, and advance adoption of improved practices for different kinds and sizes of farms.

Diverse and dynamic agricultural systems that can adjust to changing environmental and market conditions should increase the long-term financial viability and competitiveness of farms, enhance natural resource quality, contribute to the vibrancy of rural communities, and increase the food and fiber security for the Nation and the world.

Research Components

Research conducted in NP 216 is organized under four research components:

- Component 1: Agronomic Production Systems,
- Component 2. Specialty Crops and Organic Production Systems,
- Component 3. Integrated Whole Farm Production Systems, and
- Component 4. Integrated Technology and Information to Increase Customer Problem Solving Capacity

Contributing Research Units

Agricultural Land and Watershed Management Research Unit – Ames, IA
National Soil Dynamic Laboratory – Auburn, AL
Crops Systems and Global Change Laboratory – Beltsville, MD
Sustainable Agricultural Systems Laboratory – Beltsville, MD
Dale Bumpers Small Farms Research Center – Booneville, AR
Forage Seed and Cereal Research Unit – Corvallis, OR
National Peanut Research Laboratory – Dawson, GA
Agricultural Systems Research Unit – Fort Collins, CO
Central Great Plains Research Station – Akron, CO
Northern Great Plains Research Laboratory – Mandan, ND
Genetics and Precision Agriculture Research Unit – Mississippi State, MS
North Central Soil Conservation Research Lab – Morris, MN
New England Plant, Soil, and Water Laboratory – Orono, ME
Soil and Water Conservation Research Unit – Pendleton, OR
The Vegetable and Forage Crop Research Unit – Prosser. WA
Land Management and Water Conservation Research Unit – Pullman, WA
U.S. Agricultural Research Station – Salinas, CA
Northern Plains Agricultural Research Laboratory – Sidney, MT
Crop Production Systems Research Unit – Stoneville, MS
J. Phil Campbell Sr., Natural Resource Conservation Center – Watkinsville, GA

Cooperation within ARS

ARS's national programs are uniquely positioned to play an important national role in research to understand production systems and sustainability. In addition to NP216, other ARS National Programs are making significant contributions to improving the productivity, profitability and environmental sustainability of the Nation's croplands. These programs include: Agricultural and Industrial Byproducts; Water Availability & Watershed Management; Bioenergy; Pasture, Rangeland, and Forage Systems; Crop Protection & Quarantine; Crop Production; Climate Change, Soils & Emissions; Animal Production Systems; Food Safety; and Plant, Microbial, and Insect Genetic Resources, Genomics, and Genetic Improvement.

Because of space limitations, the accomplishments of projects in other national programs related to agricultural systems and sustainability are not included in this report unless NP216 scientists were collaborators.

The Use of References in the Report

The accomplishments summarized in the report are supported mainly by references in peer-reviewed scientific publications. In some cases, references to scientific presentations and abstracts are used when accomplishments are recent and there has not been sufficient time to publish. A nearly complete listing of peer-reviewed publications arising from NP 216 research projects is included as Appendix A.

AGRONOMIC CROP PRODUCTION SYSTEMS

The Action Plan Component *Agronomic Crop Production Systems* addresses research problems in agricultural systems dominated by the commodities including corn, soybean, cotton, peanut, wheat, barley, and turf and forage seed crops. The primary focus of research in this component is on understanding the underlying agroecological principles for how farms function so that new technologies and production strategies can be developed to increase production efficiency and profitability, while enhancing natural resource quality.

Diversifying Cereal based Production Systems

The concept of dynamic agricultural systems allows farmers to make production adjustments in response to major changes in international markets, weather, or government policies. This approach proposes to reverse the trend toward specialization, and instead broadens the options available to help farmers better compete. This approach for precipitation-limited environments challenges the general strategy of planting just wheat every other year – alternately leaving soil fallow to store enough water over two seasons to grow one year of crop. This is not the ideal situation for farm economic return or the environment. Leaving the field fallow degrades the soil by decreasing its organic matter while increasing the likelihood of erosion. The rotation also wastes a lot of water through evaporation when the soil is managed to be bare.

ARS research is determining how farmers in the Great Plains and inland Pacific Northwest can maximize precipitation use efficiency by diversifying wheat-based production systems with additional crops and use conservation tillage methods where possible without plowing first to obtain the greatest economic return while minimizing expenses and risk each year.

At Mandan, ND, research demonstrated using a dynamic approach to enhance soil quality and productivity in the Northern Great Plains. Scientists there have used an extensive series of controlled field investigations to look at 100 combinations of 10 crops grown in rotation sequences: barley, canola, crambe, dry bean, dry pea, flax, safflower, soybean, sunflower, and spring wheat. A second study expanded the research to include additional rotation crops including: buckwheat, canola, chickpea, corn, dry pea, lentil, proso millet, sorghum, and spring wheat This research led to the concept of 'Dynamic Cropping Systems (Liebig et al., 2007; Tanaka et al., 2007; Hanson et al., 2007) which allows farmers to choose from various management options such as diversified crop sequences (Krupinsky et al., 2006; Merrill et al., 2007) and livestock to obtain the greatest economic return while minimizing expense and risk each year. To make the information easily accessible, a free *Crop Sequence Calculator* on CD-ROM was released to help agricultural managers choose from among the many crop combinations that have been investigated. ARS scientists are doing similar research at several locations across the Wheat Belt at Akron, CO, Sidney, MT, and Pendleton, OR, and Pullman, WA.

ARS scientists in Sidney, MT have selected a set of diversified production system options for growers in the eastern Montana – western North Dakota region of the northern Great Plains that utilizes spring wheat only every third or fourth year and can replace traditional wheat-summer fallow systems. The rotated wheat had greater yields and higher quality grain compared to conventional spring wheat systems that grew wheat continuously or every other year. Field pea grown every third or fourth year also had higher yields and fewer weeds compared to pea grown every other year in rotation with spring wheat, and compared to spring wheat grown continuously or planted every other year. When the systems are further diversified with annual cool-season forages, pesticide use is decreased and there is increased pea and spring wheat yield and productivity. A five year experiment compared yield, quality, and water and nitrogen use of durum-fallow rotations with two-year rotations of continuous durum and three annual forages: forage barley, forage barley interseeded with field pea, and foxtail millet. Averaged over the entire multiple year rotation, preplant soil water and residual nitrogen content were greater for durum following fallow than for durum following annual forages, resulting in reduced total fertilizer N requirement and greater yield, water use, grain N accumulation and nitrogen recovery index (NRI) following fallow (Lenssen and Cash, 2011; Sainju and Lenssen, 2011a, b; Allen et al., 2010). Annual spring-seeded forage crops use less water than cereal grains, including durum, and may be a suitable replacement option to summer fallow. Replacing summer fallow with annual forages reduced durum grain yield by 10.8 bushel per acre, but forage yields of nearly 2.5 tons per acre produced a higher annualized return over the five-year study period for all three wheat-forage rotations ($51, $31, and $14 per acre, respectively).

Cool-season bioenergy crops for sustainable second generation biofuels production may be able to replace summer fallow in rotation with spring wheat in the Northern Great Plains. ARS scientists in Sidney, MT, and a SDSU collaborator conducted a field trial near Froid, MT, to determine yield, quality, weed and insect pest communities, and water and nitrogen use of three diverse cool-season oilseeds in two-year rotations with durum under dryland conditions. Averaged over four years, seed yield of *Brassica juncea* canola exceeded that of camelina while crambe was intermediate. Oil yield of *B. juncea* was greater than for crambe and camelina. Three-year mean grain yield of durum following the oilseeds did not vary among preceding oilseed crops; conversely, yield of durum following fallow was about 50% higher. Oilseeds and durum following oilseeds used similar amounts of water, but durum following fallow averaged three inches more water use due to increased storage during the previous year’s fallow. Canola-quality B. juncea had superior seed and oil yield compared to crambe and camelina entries. However, when replacing summer fallow, all oilseed entries similarly decreased yield of the following durum crop. Although these results have not yet been published, they are already having a positive impact on national planning efforts for sustainable aviation fuel production, and are the basis of new sustainability studies in the Pacific Northwest and Northern Great Plains regions for the USDA Biomass Research Center.

When combined with zero-tillage planting, weed seed production is greatly reduced compared to conventional management and other pre-plant tillage systems. Early-planted forage barley can prevent all weed seed production without herbicides (Lenssen 2008). Fall-seeded, zero-tillage winter wheat and triticale produced without an herbicide application during the growing season provides high yields of nutritious forage without weed seed production. Land rolling following pre-plant tillage increases the emergence of small-seeded broadleaf annual weeds in annual pulse and forage crops, thus providing opportunities to increase weed seed bank depletion (Lenssen 2009).

Soil aggregate stability improved over 12 years of no-till continuous spring wheat systems compared to wheat-fallow rotation with the values approaching those of samples from nearby perennial grass fields, and long-term, continuous wheat-lentil rotations did not differ in aggregate stability compared to a wheat-fallow rotation. Leaving lentil residues on the soil surface to control erosion was shown to minimize nitrogen (N) mineralization, thus making more N available to the subsequent crop. The amounts of carbon and nitrogen in the soil surface residues were 23 to 141% greater than in the conventional system, so leaving moderate amounts of lentil residue on the soil surface in no-till wheat-lentil rotations was found a better alternative than fallow or tilled lentil-wheat systems At Akron, Colorado ARS researchers found similar results in long term intensive no-till rotations (Mikha et al., 2010a,b). In those experiments, both increases in soil C and aggregate stability were measured in intensive crop rotations over time. Whereas with the wheat-fallow systems soil C and aggregate stability were always less than in the intensive no-till systems. These increases in soil quality parameters were linked to a corresponding decrease in soil bulk density in plots receiving less tillage and more intensive cropping.

Like farmers in the northern Great Plains, those in the Central Great Plains region (parts of Colorado, Wyoming, South Dakota, Nebraska, and Kansas) have traditionally grown wheat one season and left the ground fallow the next year. In 1990, a team at Akron, CO began a long-term crop rotation study with 23 rotation combinations. Over the years rotations that weren't successful were ended and other new combinations begun. Each phase of each rotation is grown each year to get results quicker. Also, because weather is so variable in the region, all crops in all rotations are observed in dry and wet years. Among the crops included were: corn, peas, proso millet, safflower, sunflower, triticale, and winter wheat, with some crops grown for grain and some for forage. The best rotations have usually lasted three or four years, such as growing wheat the first year, corn the second, and then leaving the field fallow for the third (wheat-corn-fallow). Two other rotations that proved successful were wheat-corn-mille-fallow and wheat-millet-fallow (Vigil et al., 2008; Nielsen et al., 2011).

Controlling management to effectively utilize available soil water was the key factor of rotation system success. Each crop takes up water differently. Sunflower plants, which have deep roots, use nearly all the water stored in the soil each season, while shallow-rooted millet uses much less. Several of the successful systems have no water-wasting summer fallow periods between crops (Nielsen et al., 2011).

The amount and type of crop residue and how that residue is managed also affects precipitation storage efficiency and therefore crop yield the next year. Corn yield was about 15% lower in the rotations of wheat-corn-millet and wheat-corn-sunflower-millet than in wheat-corn-millet-fallow and wheat-corn-fallow rotations. This is because wheat residue production is less following millet than following fallow, resulting in lower precipitation storage efficiency and lower available soil water for corn. The method of residue management can also impact yield. Ten to twenty bushels more corn were produced following wheat when using a wheat stripper head-harvested wheat instead of conventional combine harvester– the difference being how the residue was managed at harvest with the same amount of residue produced. Sunflower did best when grown once in four-year rotations because of reduced insects and diseases. Corn and sunflower had the most yield variability in the studies; wheat and millet had the least. Just like financial advisors suggest diversifying your financial portfolio to protect against variability, a diversified crop rotation strategy can be used to minimize weather variability impacts (Nielsen and Vigil, 2010).

Local farmers have noticed how successful the crop rotation research has been and have started to change their farming practices. Corn, millet, and sunflower acreage have gone up dramatically near the research center. Ken Remington, who runs a 1,000-acre farm about 25 miles from Akron, has changed from a mostly wheat/fallow rotation to one that uses corn and millet and has experimented with other demonstrated alternative crops. Remington said that the wheat/fallow rotation was not really economic for him, while the corn rotations are three times more profitable than the wheat ones. Another farmer, David Wagers, changed the rotations on his 6,000-acre farm from a wheat/fallow rotation, partly because of the ARS research. He now changes rotations based on what is profitable at the time, but usually includes wheat and corn and either millet, sunflower, or fallow. It has been noted that many farmers may be reluctant to switch from conventional wheat-fallow to the more intense no-till rotations because they'll have to buy additional equipment and learn about insect, weed, and disease cycles and markets for the new crops. Two new rotations that include canola were added in 2010. These rotations are being evaluated for crop-water use and yield relationships under no-till management comparing wheat-canola-corn-fallow rotation to a continuous rotation of wheat-corn-millet-canola. Economic yield, total biomass yield, crop-water use, and soil water storage is measured in each plot each year.

Inland Pacific Northwest. Pacific Northwest farmers plant around 2.2 million acres of winter wheat every year, and between 1.3 to 22 tons of silt-loam soil erode from each acre in production. Despite the obvious soil losses due to erosion, Pacific Northwest farmers generally use conventional tillage in their winter wheat production consisting of one or two passes with a moldboard or chisel plow followed by three or more passes with a rod weeder. At Pendleton, OR, water runoff amount, soil erosion, and crop yields in a conventional, intensively tilled winter wheat-summer fallow system were compared to a no-tillage, four-year crop rotation of winter wheat, chemical fallow, winter wheat, and chick pea (Williams et al., 2009). Though there was no difference in yields between the two systems, it was discovered that 70% more runoff and 52 times more eroded material escaped from the conventional-till fields than from the no-till fields. Of all precipitation events from 2001 to 2004, 13 events generated erosion from conventionally tilled fields, but only three events resulted in erosion from no-till fields. These findings show that if wheat producers in eastern Oregon and Washington used no-tillage systems, they could substantially stem soil erosion and enhance water quality and not lose any crop yield. It was also found that the no-tillage soils eroding down-slope moved much more slowly over time, unlike more sudden and severe erosion events that are typical of regions with heavy precipitation. No-tillage production improved levels of soil organic carbon that were translated into greater soil aggregation that in turn increases soil stability.

Soils in the Pacific Northwest are extremely vulnerable to erosion by overland flow of water. A conservation tillage practice such as disking or chiseling followed with a cultivator or sweep-rod leaves more than half of soil surface covered by crop residue, but still may result in rill formation and soil erosion. At Pendleton, OR, scientists compared the infiltration, runoff, and soil erosion from conservation tillage and no-tillage combined with a four year crop rotation of winter wheat, spring dry peas, winter wheat, and fallow (Williams and Wuest, 2011). Between 2005 and 2008, which were years of mild weather, no-tillage was superior to conservation tillage with 22 % more ground cover, 192 % more infiltration, and 55 % less soil erosion. We can expect improved soil conservation and reduced off-farm sedimentation with broader adoption of no-tillage in preference to conservation tillage.

Increasing the frequency and diversity of crops grown in a rotation has been proposed as a way to enhance long-term crop productivity. At Pendleton, OR, crop yields, production costs, and economic returns of a diverse cropping system were compared under minimum tillage with cultivation by chiseling, sweeping, and rod weeding versus no-tillage with chemical weed control (Williams and Long, 2011). The crop sequence was fallow/winter wheat/dry spring pea/winter wheat in which a broadleaf crop is included to aid in the control of winter annual weeds and reduce soil-borne cereal diseases. Over the four year study, the no-tillage and minimum tillage had equal wheat yields, but no-tillage had substantially less labor and fuel costs. No-tillage has the potential to be more economically viable than minimum tillage for intensive cropping in areas receiving more than 14 inches of rainfall in northeastern Oregon.

Pendleton scientists in cooperation with University of Idaho and ARS scientists in Beltsville, MD have developed a new spectral vegetation index that improves the ability to use remote sensing to estimate the nitrogen nutrition status of wheat (Eitel et al., 2007, Eitel et al., 2008). This information could be used to precision apply late-season nitrogen fertilizer based on wheat crop need in semiarid regions where crop canopy reflectance can be dominated soil moisture variability (Eitel et al., 2009; Long et al., 2009). In semiarid regions, nitrogen fertilizer is applied late in the growing season to boost grain protein concentration of hard red wheat so farmers can receive a premium price for meeting minimal quality standards. Precision applications of fertilizer to meet the exact crop needs of plants across variable field conditions can save costs and reduce the chance of excess fertilizer contaminating water or generating greenhouse gases. In addition, these scientists found that new green laser scanning technology is potentially useful for the same purpose, but at early growth stages of wheat (Eitel et al., 2011). Because the laser data could be processed to remove returns from soil background and leaf edges, the reflected green laser light measurements were more accurate than readings taken with hand-held chlorophyll meters and ground-based active optical sensors.

ARS scientists in Sydney, MT and Beltsville, MD used remotely sensed cellulose absorption index (CAI) to evaluate crop residue cover and the subsequent sustainability of various cropping systems in semi-arid regions (Aguilar et al., 2011). Estimates of crop residue cover measurements can be utilized in computer models to help determine and compare the amount of carbon stored in soils under different cropping systems in these western semi-arid dryland regions where a majority of wheat is produced in the U.S. The technique holds potential for many other computer model applications looking at carbon sequestration and to aid compliance with government farm conservation programs.

Other Crop Production Systems (peanuts, corn and cotton)

Years of drought in the southeastern U.S. and increasing urban usage of water resources are forcing peanut farmers to carefully consider whether irrigation actually pays and what would be the best combinations of crops to produce. Alternative irrigation methods, such as subsurface drip and sprinklers, are aimed at achieving this goal. Researchers at the National Peanut Research Laboratory (NPRL) in Dawson, GA have nearly completed a 15-year study to determine the impacts of irrigation, crop rotation, and price on peanut profitability when rotating peanuts, corn, and cotton crops (Sorensen et al., 2009). To help peanut farmers make planting, irrigation, and pest-control decisions, the results from the long-term study have been used to develop a computer program called Irrigator Pro.

In many regions, irrigation is necessary for peanuts to grow to marketable size. Irrigated acreage for crop production in Georgia has increased over the last 30 years due to recurring drought and its impact on crop yield – peanut yields in the Southeast declined 11.5 % during the 1980s, compared to the 1974-1979 period. Corn, cotton, and peanuts were grown in six rotation sequences and with four irrigation methods: over-head sprinkler, subsurface drip, surface drip, and a non-irrigated control. Water was applied at 100%, 66%, or 33% of the estimated amount of the crop water needs. The objective was to determine which scenario achieved the highest yields compared to the amount of water applied—while maximizing profit (Faircloth et al., 2010). In 2002, a drought year, peanut yields were slightly higher with 100% irrigation by sprinklers than with 66% water use replacement, but the cost of the extra water wiped out the higher-yield benefit. The profit per acre was actually a dollar higher with the lower water amount. Both irrigated treatments out-yielded non-irrigated production by more than 2,000 pounds per acre. In contrast, the rainfall pattern received in 2003 resulted in the highest average peanut yields in Georgia's history, and the per-acre profit was $64 per acre higher with 100% irrigation than with 66%. Cotton in 2002 presented a somewhat different picture. Cotton prices were low enough—about 50 cents per pound—that 100 % irrigation returned a small yet positive return, while 66 % irrigation resulted in only a $2 return to the grower. But in the wetter 2004, both schemes returned a profit: $140 per acre for 100% irrigation, and $76 for 66%. For corn in 2002, 100% irrigation returned $23 profit per acre, but 66% irrigation left a deficit of $5 per acre. It got much worse with less water: losses of $94 per acre at 33% irrigation and $144 with no irrigation. Because irrigation is costly, farmers must carefully balance the crop yield response, crop price, and irrigation cost to ensure profitability (Lamb et al., 2010).

Farmers cannot grow just one crop, and the price of different crops in rotation determines profitability. A rotation of cotton-cotton-peanut consistently provides greater profit than the other rotations. The second most profitable rotation is cotton-corn-peanut. If the crops are receiving low prices, then the cotton-cotton-peanut rotation is about $57 per acre more profitable than the cotton-corn-peanut rotation. At medium pricing, cotton-cotton-peanut garners $46 per acre more than cotton-corn-peanut. And when high prices can be had, cotton-cotton-peanut realizes an additional $24 per acre more than medium pricing (Lamb et al., 2011).

The Dawson peanut production systems research results have been integrated into Irrigator Pro to help farmers make better irrigation management decisions based on economics and not simply yields. The decision tool Irrigator Pro has been released as part of a collection of software called FarmSuite update 5.0. This management system, updated with new data, allows peanut, cotton and corn growers to use volumes of research data and grower experience to make daily decisions about their production, harvesting and marketing. This software program has been extensively validated with long-term controlled research studies, as well as commercial trials with cooperating farmers. Use of this software will help farmers reduce water consumption by their crops, reduce pesticide applications, and increase the yield and profitability of corn, cotton, and peanut crops. Adoption of the software by producers and crop consultants in Georgia, Florida, and Alabama has exceeded expectations (Lamb et al., 2010).

Conservation systems are another management tool for peanut production that consists of non-inversion tillage and high residue cover crops. Traditional peanut production includes multiple conventional tillage operations to prepare a seedbed, but these methods exacerbate poor soil structure and low soil organic matter contents typical of many southeastern peanut production areas. Conservation tillage combined with cover crop residue can maintain or exceed traditional yields, promote water infiltration that can increase irrigation efficiency, which lowers pumping costs and water requirements, and increase dryland peanut drought tolerance during short term dry periods (Balkcom et al., 2010).

Conservation tillage can be a viable option for peanut production, but typically consists of a strip-tillage operation that disrupts up to 1/3 of the row width. Producers that grow peanuts in twin-rows are concerned that reducing the tilled width of the row to maximize ground cover retention will reduce seed to soil contact and negatively impact twin row peanut production. Researchers at the National Soil Dynamics Laboratory (NSDL) in Auburn, Alabama compared narrow and wide strip tillage systems across single and twin row peanuts. Narrow strip tillage across both row configurations maintained 16% more beneficial surface residue following planting compared to wide strip tillage. Peanut yields and grades, a measure of peanut quality, across narrow strip tillage systems were equivalent to peanut yields across wide strip tillage systems (Balkcom et al., 2010).

The belowground fruiting habit of peanut creates a unique challenge for soil quality management because of the digging operation required, prior to harvest, that promotes oxidation of soil organic matter. This creates the need to preserve as much residue as possible to ultimately increase soil organic matter and subsequent benefits including moisture conservation. This information indicates that peanut growers can maintain yields and grade while maximizing surface residue retention with narrow strip tillage systems on degraded Coastal Plain soils across the Southeast (Balkcom et al., 2010).

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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 agricultural products. Since the late 1990s, U.S. organic production has more than doubled, but the consumer market has grown even faster. Organic food sales have more than quintupled, increasing from $3.6 billion in 1997 to $21.1 billion in 2008 (Greene et al., 2009). The production of high-value specialty and organic crops often requires cost-intensive practices to achieve profitable production levels for 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 grown in their region. 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.

In an effort to identify management practices that:

- utilize on-farm resources and natural ecosystem processes,
- identify practices that reduce purchased inputs,
- indentify practices that reduce pesticide use,
- identify practices that reduce whole-system costs and risks, and
- identify practices that enhance market quality,

the Agricultural Research Service conducted research and made several scientific contributions in the following research areas.

Cover Crops in Sustainable and Organic Cropping Systems

Cover crops have potential for protecting soil from erosion, accumulate excess nutrients, and therefore protect water resources from off farm environmental impacts. In addition, legume cover crops improve nitrogen (N) nutrition for subsequent crops. Also, because of their biological competiveness, they can reduce agrichemical (herbicide) use. Some cover crops (*Brassica* species) reduce disease infestation in potatoes. ARS research over the past five years with cover crops resulted in many useful accomplishments that have increased the sustainability of US agricultural systems (Dabney et al., 2010).

With the legume winter cover crop hairy vetch (*Vicia villosa*), ARS researchers documented that vetch biomass can be used as an organic N-rich mulch. This high N mulch resulted in inorganic N contributions (through N mineralization) that were great enough to reduce chemical fertilizer N inputs by up to 50%. Legume cover crops can substitute for and reduce fertilizer N inputs in different cropping systems. On the other hand ARS scientists in the Sustainable Agricultural Systems Laboratory at Beltsville, MD researchers also found that sweet corn yields are reduced when using legume cover crops as the sole source of N (Teasdale et al., 2008). In this three-year field experiment the N released from hairy vetch cover crops was not as effective as chemical N fertilizers. Fewer marketable ears were produced by sweet corn grown on N released from a decomposing hairy vetch cover crop than by corn grown on synthetic N released from fertilizer. The lower crop use efficiency of N 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.

Researchers also documented vetch mulch protected soil from water erosion and reduced pesticide loss in runoff (Rice et al., 2007). Soil sediment and rainwater volume were reduced by an estimated 70-90%, while cover crop residues adsorbed pesticides and reduced their movement into surface water by an estimated 75 to 90% compared to traditional polyethylene mulch. Hairy vetch, planted in the fall, establishes cover before becoming dormant in winter. In spring, the plants make abundant growth and through symbiosis fix large quantities of N. In late spring, the vetch plants can be tilled into the soil or rolled down and killed, leaving a 3/4-inch-thick thatch of dead stems that serves as weed-smothering mulch. This mulch also keeps moisture in the soil, slows down runoff, and protects soil from erosion. Hairy vetch's main contribution to soil is through increased N nutrition which is utilized by the subsequent high value "main crop" (corn, tomatoes, or pumpkins are examples).

The adoption of vetch as a cover crop has been restricted by the late-flowering characteristic of available varieties. When the vetch is terminated, using a mechanical roller/crimper operation before vetch flowers, it re-grows and competes with the main crop. A new variety, Purple Bounty, was developed by USDA-ARS scientists in the Sustainable Agriculture Systems Laboratory at Beltsville, MD, in cooperation with Pennsylvania State University, the Rodale Institute, and Cornell University. Purple Bounty flowers 2 weeks earlier than the traditional standard varieties. This allows farmers to plant their main crop earlier in spring and use higher yielding cultivars of corn and tomatoes that require a longer growing season. Also, until now, the use of hairy vetch had limited adoption north of Maryland because of poor winter survival. Purple Bounty includes traits for both early flowering and improved winter survival. The availability of Purple Bounty will likely encourage greater adoption of legume cover cropping in US farming systems and increased flexibility in grower farming operations.

In a long-term cropping systems study at the Crop Improvement and Protection Research Unit in Salinas, CA, USDA-ARS scientists with university and grower cooperators showed that different cover crops produce similar amounts of final biomass, but had large differences in their weed suppressive abilities. At typical seeding rates, weed suppression by mustard and rye was excellent, but extremely poor in legume/cereal mixes. Increasing the seeding rate of the mixes improved weed suppression to acceptable levels. Over an eight year period, higher seeding rates in a legume-rye mixture reduce weed management costs, and that frequent cover crops increased vegetable yields by several fold. In on-farm component studies with local organic farms, rye and legume-oat cover crops at high seeding rates consistently improved weed suppression but that planting in a grid pattern, which is more difficult to do than standard planting, had no effect on cover crop yield or weed suppression. Furthermore, grid planting requires two passes through a field instead of just one, grid planting would likely double dust production, fuel use, planting time and labor (Brennan et al., 2009)

High residue cover crops have been adopted across portions of the Southeast. In these systems the cover crop is crushed with rollers before planting the subsequent summer row crop (cotton). Vegetable growers are beginning to adopt high residue cover crops, but since many vegetables are produced on raised beds, roller designs must be modified to match bed configuration. ARS researchers at Auburn, AL have been awarded patents for three innovative roller/crimper designs for managing cover crops in raised vegetable beds. The first patent is a roller/crimper for elevated bed culture (Kornecki, 2009), and the second is a smooth roller/crimper with a crimping bar that has a spring-adjustable crimping force (Kornecki and Raper, 2009). The third patent is a two-stage roller/crimper to work effectively with both large and small tractors (Kornecki et al., 2009; Kornecki, 2011). A fourth roller/crimper was developed (Kornecki, 2010, U.S. Patent pending) for small organic vegetable farms that have power sources limited to self-propelled walk-behind garden tractors. Termination rates of 100% were achieved two and three weeks after rolling with the powered roller/crimper, which was similar to terminations rates observed with larger and heavier roller/crimpers. There has been considerable interest from the organic farming community in the Southeast about obtaining the powered roller/crimper implement. The smooth roller/crimper and the two stage roller/crimper were further tested with different herbicide application methods and rates. Results indicated that applying herbicide every fourth crimp was as successful as continuous spray in terminating rye one week after rolling. By eliminating the continuous spray, an 80% reduction in herbicide use was achieved (Kornecki et al., 2010). Proper roller management reduced herbicide use in summer row crops as well. When winter cover crops (black oat, rye, and wheat) were flattened with a straight-blade mechanical roller-crimper, followed by herbicide applied at low rates (less than half the standard) these mature cereal cover crops were reliably terminated. Timely cover crop termination ensured cotton establishment and protected growth. Also, rolling mature winter cereal cover crops will likely conserve greater soil moisture when compared to standing covers.

Because weeds are a particular problem in organic systems, ARS organic research has also focused on weed suppression with cover crops. In that effort, ARS researchers documented that the timely use of a rotary hoe reduces weed seed production in winter cover crops by up to 80%, so weeds are less of a problem in the subsequent crop (Boyd and Brennan, 2006).

Cover crop mixtures of legumes and cereals combine the nutrient scavenging abilities of cereals with the N-fixing ability of the legumes. Such mixes reduce losses of N to ground and surface water, and reduce the need for expensive supplemental N fertilizers. Novel mixtures of legumes and cereal were evaluated by ARS scientists for biomass production, N content and weed suppression in on-farm trials in Salinas and Hollister, CA. Mixtures of 90% legumes (*Vicia* spp. and peas) and 10% cereals (rye or oats) versus 60% legumes and 40 percent cereals were evaluated. The percentage of legume biomass of total cover crop biomass in the mixtures declined across the season, especially in the 60% legume mixtures at the higher fertility site. This research provides farmers with critical information that helps them choose cost effective cover crop mixtures that suppress weeds and increase N fertility in vegetable rotations (Brennan et al., 2011).

USDA-ARS scientists at the Vegetable and Forage Crop Research Unit at Prosser, WA further assessed the fate and N cycling from a mustard cover crop to potato under center pivot sprinkler irrigation (Collins et al., 2007). The aboveground mustard cover crop recovered 34 to 51% of the fertilizer applied. The total aboveground biomass and N uptake by the cover crop ranged from 4.6 to 7.5 Mg ha and 92 to 142 kg N per ha, respectively. About 29% of the N in the cover crop was cycled and absorbed by the following potato crop showing that the mustard cover crop can provide 30 to 40 kg N per ha toward the N requirement of a subsequent potato crop.

Controlling Pests of Potato

Farmers in the Pacific Northwest have also found that the use of *Brassica* cover crops (white and brown mustards, *Brassica hirta*) in rotation with potatoes (*Solanum tuberosum L.)* reduces potential wind erosion and serves as a biocontrol method for a number of plant pathogens. Brassicas in rotation with potato or when used as cover crop, can reduce disease and pests in potato**.** In long-term rotation trials, ARS scientists at the New England Plant, Soil, and Water Laboratory at Orono, ME, determined that canola and rapeseed in rotation with potato consistently reduced soilborne potato diseases (black scurf, canker, and common scab). Average reductions were 18 to 38% over a ten-year study period. The addition of winter rye as a fall cover crop, combined with the effects of a *Brassica* rotation crop reduced black scurf and common scab by 25 to 41% (Larkin et al., 2010). In other research with verticillium-wilt (a persistent soilborne disease of potato), the potential disease-suppressive effects of mustard green manures were determined. Mustards were found to reduce verticillium wilt in potato by 25%, but that multiple years of disease-suppressive crop cultivation were needed to maintain low disease levels (Larkin et al., 2011a). This research provides growers with specific information on rotations useful for naturally controlling these important diseases. The research also provides farmers information on how best to integrate these rotations into a production system. In a similar fashion, soilborne potato diseases may be controlled by “biofumigation” with Brassica green manures. On-farm field trials showed that mustard, canola, and rapeseed green manures reduced powdery scab of potato by 15-40%, and canola and rapeseed reduced potato black scurf by 70-80% (Larkin & Griffin, 2007). A mustard green manure also reduced potato 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. Additional field trials with a disease-suppressive cropping system that utilized Brassica green manures and cover crops demonstrated disease reductions of 27 to 58%. They also measured yield increases up to 35%. The combination of the disease-suppressive rotation with irrigation increased yield by 53% relative to rainfed continuous potato. (Larkin et al., 2011b). 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.

ARS researchers documented that combining biological amendments with cultural practices helps mitigate potato disease infestation. With this approach, biological amendments, including biocontrol organisms, microbial inoculants, and compost teas, increase soil microbial diversity and antagonism towards soilborne pathogens. ARS scientists in Orono, ME showed that a combining conifer-based compost and bio-control amendments resulted in a 23-48% reduction in *Rhizoctonia* infection and a corresponding increase in tuber yields of 30-50% (Larkin et al., 2009). 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% (Larkin, 2008). This research shows that combining biological and cultural practices can substantially reduce diseases and increase yields without additional use of synthetic pesticides.

In other research at the ARS lab in Maine, researchers identified the common weed hairy nightshade as a source of potato late blight. Late blight caused by *Phytophthora infestans* is a serious threat to both potato and tomato. To evaluate its potential significance, they assessed the importance of environmental (temperature and relative humidity), pathogen (inoculum load and isolates), and host factors (weed growth stage and the ability of diseased plants to produce inoculum) in controlled experiments in comparison to potato and tomato hosts. Late blight infection was greater on potato and tomato than on hairy nightshade. Disease level on hairy nightshade varied with inoculum level and weed growth stage. Because hairy nightshade occurs in a similar agro-ecosystem where potato is cultivated, and has similar environmental requirements for blight infection, proper controls are required to minimize its potential impact in serving as a refuge or source of inoculum. (Olanya et al., 2009). Results from this research show potato growers how to reduce risk of late blight by controlling hairy nightshade. The research demonstrates an added benefit of weed control that may result in disease mitigation.

USDA-ARS scientists in the Vegetable and Forage Crop Research Unit at Prosser, WA also found that hairy nightshade serves as a host for the potato root-knot nematode (Boydston et al., 2007). They further documented that resistant lines of potato can be negated by the presence of the weed. 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 were shown to segregate in response to nematode damage on tubers when grown in the presence of 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 value of growing resistant potatoes that lack tuber resistance. The research also documents the importance of weed control on managing plant parasitic nematode populations. Commercial potato breeders can use this new information to select for root and tuber resistance in breeding materials.

Corky ringspot disease (CRS) of potato is caused by tobacco rattle virus (TRV). The disease makes tubers unmarketable on approximately 5% of the potato acreage of the Columbia River Basin. Soil fumigation, costing $200 per acre, is the current method of control. ARS researchers in Prosser, WA documented that growing weed-free alfalfa cleanses CRS from soil. Several weed hosts of TRV and its nematode vector were identified. Researchers then found that when the weed-hosts of the disease are present in the crop rotation, the nematode vector population is also present and waiting to infect the subsequent potato crop. By controlling weed hosts for CRS/TRV vectors, growers are able to reduce the disease in the subsequent potato crop. This method reduces the need for costly soil fumigation, saving the potato industry approximately $1.5 million dollars annually.

The potato cyst nematode, *Globodera pallida* (PCN), a restricted pest in the U.S., was first reported in Idaho in 2006. The federal government and the Idaho Department of Agriculture hope to eradicate PCN. Eradicating PCN will require depriving the nematodes of their hosts (potatoes, tomatoes, and various weeds) over a protracted time period. The host status of PCN found in Idaho has not been documented. ARS scientists conducted host suitability tests on common weeds in potato fields of the Pacific Northwest. Reproduction of PCN occurred on hairy nightshade (*Solanum physalifolium*) biotypes from Idaho and Washington, while other nightshade types from ID and WA were relatively poor hosts (Boydston et al., 2010). PCN did not produce new cysts on redroot pigweed (*Amaranthus retroflexus*), kochia (*Kochia scoparia*), and common lambsquarters (*Chenopodium album*). Control of hairy nightshade during the eradication of PCN from infested fields increases the likelihood of successful eradication of PCN.

Organic Production Systems

The cost for hand-weeding labor in high-value organic vegetables is between $500 and $6000 per acre. USDA-ARS scientists and cooperators in Salinas, CA conducted on-farm research to evaluate the effectiveness and costs of six organic weed management tools to prepare stable 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. This research identified effective methods to help organic producers minimize the cost for hand weeding of high value vegetable crops (Boyd et al., 2006).

Organic growers can now take advantage of a biodiesel byproduct for weed control. ARS scientists in Prosser, WA documented the use of leftover mustard (*Sinapis alba*) oilseed-meal as an organic weed suppressor (Boydston et al., 2011). They found that the seed meal produced when mustard seed oil is extracted is high in glucosinolates, compounds that inhibit weed germination and establishment. The mustard seed meal was effective in controlling annual weeds for about three weeks after application without significant injury to the crop when applied after the 2-leaf stage of onions or to dormant peppermint. Application rates of 1 to 2 tons per acre of mustard seed meal can substantially reduce the cost of hand weeding. The end result is lower costs for producing organic peppermint and onions.

Proponents of organic farming have proposed that organic systems may be more resistant to spikes in weed seed production than conventional systems. The argument is that the viability of weed seed in the soils of organic systems is less persistent. The lower persistence, a result of greater microbial activity in the high organic matter soils characteristic of organic systems. Comparison of weed seed persistence in soils of two long-term cropping systems (organic and conventional) studied by ARS, Beltsville, MD and the Rodale Institute, Kutztown, PA, showed that weed seed persistence was relatively short (half-life of approximately one year) with only small differences (a couple of months) in half-life between organic and conventional systems (Ullrich et al., 2011). Also, seed half-life correlated poorly with measures of soil microbial activity and organic matter content. Results suggest a need for a greater mechanistic understanding of the factors responsible for weed seed longevity in soil.

In other organic weed research, ARS scientists in Beltsville, MD showed that diverse rotations could reduce weed seed numbers in the soil seed-bank, leading to improved weed control. During favorable years, corn yield losses due to weeds were less than 5% in the longest organic rotation (Teasdale and Cavigelli, 2010). These yield losses were similar to what is achieved using herbicides in conventional no-till and chisel-till systems. Crop yield loss from weed competition is particularly troublesome for organic farmers because herbicides are not used to control weeds. This research indicates that with good management, longer organic crop rotations can adequately control weeds. Also, this long-rotation strategy should be of value to conventional producers for reducing herbicide rates and preventing the development of herbicide-resistant weeds. These results are of great benefit to growers considering the economics to transition from conventional to organic systems.

Conventional cropping systems have been criticized as being unsustainable because they can contribute to environmental degradation (on-farm and off-farm) and are often economically uncertain. USDA-ARS scientist at Prosser, WA identified changes in soil chemical and biological properties in a semiarid shrub-steppe ecosystem converted to irrigated organic production in the Columbia Basin of Washington State (Cochran et al., 2007). Disturbance from conversion to irrigated crop production improved total organic carbon (C) and nitrogen (N) storage, C and N mineralization, and C turnover. Organic fields had greater concentrations of total organic C and N and higher cumulative C and N mineralization than native sites after 3 years of cultivation. Cultivation, crop residue incorporation, dairy manure compost amendments and irrigation all contributed to the increase in total soil C.

Researchers at the USDA-ARS Vegetable and Forage Crop Research Unit at Prosser, WA improved the environmental and economic sustainability of irrigated potato systems (Alva et al., 2009). This was accomplished by reducing production costs, through conservation tillage and reduced inputs. The conservation tillage strategy in a sweet corn/sweet corn/potato rotation reduced the total number of passes from nine to six and soil disturbance operations from seven to four, including harvest, compared to those under Conventional tillage management. Disease organisms *Pythium spp*, *Fusarium spp*. and *Verticillium dahliae* populations declined by the end of the first cycle. Application of reduced tillage in this rotation did not adversely affect potato yields and showed a positive influence on soil properties after three years of conservation tillage.

Researchers at ARS in Beltsville, MD estimated the global warming potential of no-till, chisel till and organic cropping systems at the long-term Beltsville Farming Systems Project (Cavigelli et al., 2009a). In their study, organic cropping systems that included poultry manure additions resulted in greater increases in soil carbon and lower energy use compared to conventional Maryland farming systems that used chemical fertilizers, herbicides and tillage management. Despite 25-30% lower yields in the organic systems, the calculated ratio of global warming potential per unit of crop yield was significantly higher in conventional no-tillage and chisel-tillage than in organic systems. Practices common in organic systems, including incorporating legume cover crops and animal manures into soil, help reduce the “carbon footprint” of agriculture compared to conventional systems, primarily by increasing the amount of carbon in the soil. These results are valuable for policy makers, farmers, and those interested in quantifying the impact of agriculture on global C cycles and potential climate change.

In another study, ARS scientists at Prosser, WA identified the effect of N-fertilization, and tillage on trace gas emissions in a potato rotation (Haile-Mariam, et al., 2008). Potato production in sandy irrigated soils with intensive fertilization is a common practice in eastern Washington. This management practice results in increased tuber yield but also influences trace gas (CO_2, N_2O, and CH_4) production/consumption. Methane uptake in a native site was 1.5 times greater than in potato and corn fields. Emission rates of N_2O and CO_2 were higher at time of fertigation, but were not significantly influenced by crop or tillage practice. Cumulative, CO_2 and N_20 fluxes from corn and potato fields were 14 and 22 times greater than the native site, respectively. N_20-N losses accounted for 0.35% (0.5 kg N ha^{-1}) of the applied fertilizer. This low value is due to split applications of fertilizer through the irrigation system during the growing season.

ARS researchers at Prosser further documented that soil organisms can be used as indicators of dynamic soil quality because their community structure and population density are sensitive to management changes. ARS scientists found in an organic vegetable production system that soil properties affected soil organisms and spatial variability can confound their utility for soil evaluations. ARS scientists documented the relationship between two important agronomic soil parameters, N-mineralization potential and aggregate stability, and the biological, chemical, and physical properties of the soil being characterized (Collins et al., 2011). Soils with high biological activity exhibited the greatest N-mineralization potential and formed more stable soil aggregates.

Increased soil aggregation was associated with larger nematode populations. Tillage had a strong effect on microflora and macroflora populations; soils not tilled for 5 years had the largest microbial biomass and soils not tilled 2 weeks before sampling had the largest nematode populations.

Improving N use efficiency in corn production will provide economic benefits to farmers and environmental benefits to society. ARS researchers in Beltsville, MD showed that the N release characteristics of locally available sources of feather meal-poultry-litter blends make them a viable source of supplemental N for grain production (Spargo et al., 2011). The rate of N release of each material was relatively fast, suggesting that applying them to corn at the V5 growth stage (sidedress) could result in significant improvements in N use efficiency compared to pre-plant applications (the industry standard). Results showed that the feather meal and the feather meal-poultry litter blend were more nutrient-dense than the raw and pelleted poultry litter and therefore less costly to transport per unit of available N than other organic sources. This information benefits producers, extension educators, and nutrient management designers, interested in improved soil fertility and nutrient management in organic and conventional grain cropping systems.

In general, there is inadequate information regarding the performance of organically produced cereal grains in the United States. USDA-ARS scientists at the Sustainable Agricultural Systems Laboratory in Beltsville, MD documented an increase in organic corn yields with an increase in crop rotation length and with an increase in crop diversity (Cavigelli et al., 2008). 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 N 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 N for crop growth and decreasing weed competition. . In addition, economic risks of production decreased with increasing length of crop rotation (Cavigelli et al., 2009b).

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, and high amounts of chemical inputs for specialized crop production. ARS Scientists at Morris, MN compared crop yields and economic returns for Corn Belt farmers considering switching from conventional corn and soybeans to a range of alternative systems (Archer et al., 2007). These alternative systems include reduced tillage intensity, increased crop diversity, and organic production. Results from their research showed that increasing crop diversity and reducing tillage intensity resulted in more stable yields over time (Jaradat and Weyers, 2011) and, generally, reduced production costs. Yields were reduced under organic production compared to conventional systems, but when considering the overall system costs, many crops under alternative management showed no significant differences in net returns. This suggests that for many crops there are no economic barriers to adopting these practices. Economic returns for most organic systems were comparable to or exceeded those from conventional systems (when organic price premiums were included). This research provides practical agronomic and economic information to farmers pondering whether to switch to alternative production systems. This research also provides important information for policy makers who may have to determine the size and range of economic incentives needed to encourage producer adoption of these practices.

Additional Research Accomplishments with Sustainable Fresh-Market Fruit and Vegetable Production Systems

USDA-ARS scientists in Beltsville, MD released U.S. Department of Agriculture, Agricultural Research Service, Farmers' Bulletin 2280 (Abdul-Baki and Teasdale, 2007) 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. Over 50,000 copies of this bulletin and preceding versions have been distributed upon request to extension personnel, growers, and gardeners, and a Spanish translation was printed for Hispanic and Caribbean farmers.

Blueberry is sensitive to drought so supplemental irrigation is essential and can improve yields by 25 to 40%. Although blueberry is the most widely distributed crop in the U.S., over 40% of lowbush blueberries produced in North America are grown in Maine, an area in which water resources are critical to salmon. In order to determine the proper amount of irrigation needed to boost yield and yet conserve water resources, ARS scientists at Orono, ME combined meteorological data with several years of field measurements to calculate crop coefficients (used to predict crop water requirements) for irrigated blueberry (Hunt et al., 2009). Crop coefficients allow water use of blueberries to be compared to other reference crops. These data allow growers to specifically determine crop water use for blueberries from readily available weather data, and substantially increase their ability to improve water use efficiency for irrigated blueberry production.

Consumer dependence on centralized and distantly produced fresh market produce makes large urban centers vulnerable to risks of interrupted food supplies. These risks could be due to either pandemic health issues or natural disasters. Over the past forty years, many of the small farms and the associated infrastructure needed to support locally sourced foods in the Eastern Seaboard region have been lost. To proactively reverse these trends, ARS scientists at Orono, ME and Beltsville, MD, together with the USDA-Economics Research Service, the USDA-Agricultural Marketing Service, the Massachusetts Institute of Technology, Tufts University, Iowa State University, and Pennsylvania State

University, are determining how local-based production systems could be redesigned to meet a greater portion of regional food demand. They are also investigating systems redesigned to increase food diversity in the region. This research project was initiated to determine the biophysical capacity of local production systems to meet Eastern U.S. market demand. Economic and biophysical modeling decision tools are needed to construct an efficient regional food supply chain. The goal is to understand how to construct a regional food supply chain that is based on local production and that deals with the challenges of urbanization, rising transportation costs, and global market competition. The project was funded by a grant from the USDA National Institute of Food and Agriculture's Agricultural and Food Research Initiative program to the PI at Pennsylvania State University beginning in 2011.

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INTEGRATED WHOLE FARM PRODUCTION SYSTEMS

The Action Plan component *Integrated Whole Farm Production Systems* addresses problems associated with the integration of specialized crop and livestock enterprises, as well as diversified agroforestry systems. Agricultural landscapes are also home to a diversity of wildlife species, and when managed properly, can enhance habitat quality. Agricultural producers face increasing pressures to become more efficient because of increased costs of energy and other farm management inputs. Some producers have achieved increased profitability through specialized production and acreage consolidation into large farm units. Agricultural landscapes have changed as a result of greater intensive management and farm consolidation, and off-site impacts on natural resource quality increased where conservation management has not off-set those consequences. Integrating crop and livestock production elements is an alternative strategy that may reduce risks of economic loss, diversify income, and enhance environmental benefits. Similarly, including management practices that benefit wildlife habitat can help to enhance the suitability of farms and ranches for the benefit of wildlife, while still profitably conducting agricultural enterprises.

Integrated Crop and Livestock Enterprises

Extending the grazing season by the use of swath grazing not only saves money and labor but may alter near-surface soil properties. ARS scientists at Mandan, ND conducted field research to determine the impact of livestock presence on no-till grain and forage production. A rotation using combinations of oat and pea mix the first year, then a triticale and clover mix, followed by drilled corn the third year –all grown without tillage – were managed to have crop residues left in swaths after harvest for livestock grazing during the winter. Combination of no-till and annual crop rotations gave farmers higher yields, fewer crop pests, more protection against drought, less soil erosion, and more efficient use of precipitation. The need for nitrogen fertilizer could also be cut in half by planting legumes like clover and using nutrients in manure more efficiently. A comparison over a 9 year period of near-surface soil properties on integrated crop-livestock and nearby perennial grass paddocks showed no differences between systems (Liebig et al., 2011a,b). These results suggest that perennial grass pastures can be converted to winter grazed annual cropping systems without significantly damaging near surface soil quality although the wet-dry and freeze-thaw cycles of the northern Great Plains may have contributed to the results. This research thrust has demonstrated that integrating crops and livestock can save more than $4,000 per 200 cows in feed cost over a year, reduce labor costs needed for winter feeding, and provides a profitable way to recycle manure as a soil conditioner within fields (Tanaka et al., 2008) without a major reduction in near-surface soil quality. The protein-rich forage also slightly increased weight gain in cows. Swath grazing that integrates crop, forage, and livestock components into an integrated system may contribute to more sustainable outcomes for landowners in the northern Great Plains.

Wheat growers are looking for ways to reduce herbicide use and livestock producers for ways to reduce feed costs. The largest use of herbicides in Montana, including the non-selective herbicide glyphosate, is for control of volunteer wheat during noncrop fallow periods such as after harvest and during summer fallow. In collaboration with Montana State University, ARS scientists at Sidney, MT conducted a five-year study to evaluate and compare the effects of sheep grazing with chemical fallow and tilled fallow management systems on soil properties, weed community, and spring wheat yields. Grazing slightly reduced soil carbon and available nitrogen, phosphorus, and potassium contents, along with reduced soil pH, cation exchange capacity, and electrical conductivity due to reduced amounts of crop residue returned to the soil regardless if fields were tilled and not. Grazing, however, also increased soil calcium, magnesium, and sodium contents. Grazing had no effect on wheat grain and biomass yields, but reduced the need for herbicides by reducing populations of some problem weed species. The study demonstrated that properly timed sheep grazing can be an effective way to economically control volunteer wheat and other weeds and sustain crop yields by reducing selection pressure for weed resistance to glyphosate, decreasing potential leaching of nitrates, and increasing nutrient cycling in soils (Sainju et al., 2010; Sainju et al., 2011a, 2011b).

Combining winter grazing of cattle with summer field crops like cotton and peanut can generate additional income for farmers, but there also could be deleterious effects such as increased soil compaction and reduced soil carbon levels. ARS scientists at Watkinsville, GA and Auburn, AL, in cooperation the University of the Republic of Uruguay, grazed oat and ryegrass during the winter with stocker cattle, and then tested four tillage systems for the following cotton-peanut rotation. Soil compaction, water infiltration, and soil organic carbon were measured at the end of the three-year study. No-tillage resulted in the greatest soil compaction and least amount of water infiltration. However, non-inversion no-tillage used prior to spring planting reduced soil compaction, increased infiltration 83%, and increased soil carbon 38% near the soil surface (Siri-Prieto et al., 2007). Combined with a $75per acre per year greater net returns due to 7% higher cotton yields, this integrated grazing and non-inversion tillage conservation system proved successful not only for improving soil quality, but also for increasing farmer profits (Siri-Prieto et al., 2007). Combined with a $75/acre/year greater net returns due to 7% higher cotton yields, this integrated grazing and non-inversion tillage conservation system proved successful not only for improving soil quality, but also for increasing farmer profits.

Winter annual grazing combined with vegetable production can also improve profitability and sustainability of southeastern farming operations. Previous tillage work has focused on alleviating soil compaction, prior to planting traditional summer row crops like cotton and peanut; therefore, limited information exists on tillage requirements for vegetables that minimize soil compaction. Researchers in Auburn, AL examined surface and deep tillage requirements for sweet corn, field peas, and watermelons following winter annual grazing. Researchers demonstrated that sweet corn responded to a combination of surface and deep tillage, while field peas required only surface tillage to maximize yields. Watermelon responded to deep tillage alone. These results corresponded to typical rooting depths associated with these vegetables. Southeastern vegetable growers that incorporate winter grazing into their operations for diversification and additional income should be aware of potential soil compaction problems, but yields can be maintained with appropriate tillage practices (Balkcom et al., 2010).

Agroforestry Practices

ARS scientists in Arkansas are helping commercial growers of pine trees to get the most from their stands without harming the land on which the trees grow. A major economic drawback of raising pines is it can take 30 years or more for a stand to mature and turn a profit. There are several intermediate strategies that can be used to provide pine growers increased profits including harvest of straw, and after about 15 years, thinning can be used to cut down and sell the worst trees in a stand, and then it will be at least another decade before the best wood can be harvested as an additional farm income stream (Burner et al., 2011a, b).

After 8 to 10 years, depending on tree spacing and other factors, pine straw can be harvested from a stand for use as landscaping mulch. However, the needles that accumulate on the forest floor absorb the impact of raindrops, slow water runoff, and increase the land's water-holding capacity, so removing the needles can leave a forest floor vulnerable to natural erosion. Pine straw harvesting increases runoff, soil erosion, and some nutrient loss, but were decreased by harvesting every second or third year. Fungal growth and decay turn the straw that stays on the ground for more than one season into a mat that adds extra protection to the soil. The effects of removal can also be mitigated by growing forage under the pine-tree canopy to hold the soil in place when straw is removed, or to harvest the straw earlier in October instead of December so there can be some needle fall after harvest before winter precipitation. Straw harvest has no effects on tree growth and overall survival during a seven-year period, regardless of fertilizer applications (Pote and Daniel, 2008). However, other published studies have shown a decrease in tree growth with straw harvest if nutrients are not added.

Wildlife and agricultural management can go together. When one thinks of rural America, images of farms, trees, and wildlife probably come to mind. All three are tightly linked in a cooperative research program to reforest Missouri floodplains once dominated by oaks and other native trees. A priority of the ARS at Booneville, AR is to develop efficient agroforestry systems —the simultaneous production of animal forage, crops, and lumber on the same land (Garrett 2009; Udwatta and Godsey, 2010).

Certain areas of the floodplain where crops were once grown are better suited for forest patches, because trees, including agroforestry plantings, can provide a riparian forest buffer along the river that is not only a good practice conservation practice that helps reduce soil erosion and help improve water quality, but also good for wildlife conservation efforts (Walter and Pierce II, 2008; Arbuckle et al., 2009; Valdivia and Poulos, 2009; Anderson et al., 2009; and Duehr et al., 2007).

The Willamette Valley starts at the Columbia River near Portland, OR and runs south of Eugene. For part of the year, this section of Oregon can be relatively dry, but from October through May, the area averages 37 inches of rain – a little more than three-fourths its 48-inch annual rainfall. Much of the rain flows over farm fields and into seasonal channels. It's in these channels that many types of fish and other aquatic creatures dwell for part of the year. Trees and brush alongside the fields and channels are also home to birds and other wildlife. It was found that 98% of the fish found in seasonal drainages that run through grass seed farms are native to the Willamette Valley, and that the fish mostly feed on aquatic invertebrates found in the slow-moving drainages near the fields in contrast to the swift main river channel. One reason there are so many native fish in these streams is that the land use in the area has changed little over time. Much of this part of the Willamette Valley was wet prairie grassland until settlers introduced agriculture. Today's grass seed fields are somewhat similar to those original prairies, so they may provide some of the natural landscape features from the past that are mostly lost today. (Colvin et al., 2008; Floyd et al., 2009).

In the nearby trees alongside the streams and seed fields, songbirds make winter homes. ARS, Oregon State University, and University of Massachusetts researchers have found 60 of the roughly 200 Oregon bird species were found in these riparian areas. Using computer Geographic Information System tools and satellite images to compare areas where fish and birds were thriving to areas where conservation practices were used, a multiple objective optimization models was used to determine the most economical combinations of conservation practices. A new approach was developed that uses data collected from field studies to automatically calculate a water quality index that considers the relative importance of each potential pollutant by its importance to human health and environmental services (Colvin et al., 2008).

There have been concerns that farming in the western Pacific Northwest region harmed waterways. But many of the grass seed farmer's practices are designed to preserve water quality. Careful attention to timing and placement of agricultural chemicals greatly reduces the amount that might end up in streams. The implementation of no-till planting, specifically designed for grass seed production systems, also help protect water quality. Plowing before another crop is planted disturbs the soil, so nutrients and sediment could end up in surface waters – using no-till reduces that amounts of nitrogen that mineralized and leached into surface or ground waters. No-till planting not only reduces those losses, but can be better for the farmer's bottom line. Average no-till planting costs $78 less per acre than planting by conventional tillage, and seed yields are often higher with no-till practices. (Mueller-Warrant et al., 2011a,b).

ARS and Oregon State University researchers have also determined the relative differences of western Oregon agricultural and forestland uses on water quality at the watershed level. By using satellite images to identify the kinds of crops produced on fields within different parts of a watershed they were able to determine the impact of agricultural practices on natural resources and wildlife habitat. Differences in natural soil formations and land uses affect the amounts of nitrate that are loaded into surface waters, regardless of the way the soils are managed. Less nitrogen (N) is loaded into streams from forestlands in upland reaches of the Calapooia watershed, than from lowland farm field areas on the valley floor. The effects of agricultural fertilizers like phosphorus (P) and N on water quality in adjacent waters, and the factors that impact their transport to these waters are not well understood. ARS scientists in Corvallis, Oregon demonstrated that despite the varied levels of P and nitrate in the shallow groundwater of adjacent grass seed fields, P and nitrate concentrations in the Calapooia River were consistently low throughout the entire year and were attributed to both agricultural field and riparian forest soil characteristics (Griffith et al., 1997; Wigington et al., 2003; Floyd et al., 2009). This study quantified the efficacy of a mixed-deciduous riparian forest in buffering the river from nitrate and phosphorus that originated from a grass seed field adjacent to the Calapooia River in the Willamette Valley (Davis et al., 2008; Davis et al., 2011). This work confirmed the importance of riparian ecosystems, which, through their unique position in the agricultural landscape, influence nutrient cycles and reduce nutrient loading to surface and ground water (Evans et al., 2011). The finding that both agricultural and forest riparian soil dynamics diminish nutrient loading to the river and minimize potential water pollution problems provided critical information for land managers and policy makers with regards to land use along stream channels.

The practice of letting cattle graze all winter, or swath grazing, not only saves money and labor but may alter near-surface soil properties, resulting in either positive or negative effects on natural resources quality. ARS scientists at Mandan, ND conducted field research to determine the impact of livestock presence on no-till grain and forage production (Tanaka et al., 2008). A rotation using combinations of oat and pea mix the first year, then a triticale and clover mix, followed by drilled corn the third year –all grown without tillage – were managed to have crop residues left in swaths after harvest for livestock grazing during the winter. Combination of no-till and annual crop rotations gave farmers higher yields, fewer crop pests, more protection against drought, less soil erosion, and more efficient use of precipitation. The need for nitrogen fertilizer could also be cut in half by planting legumes like clover and using nutrients in manure more efficiently. This integrated crop with livestock system can save more than $4,000 per 200 cows in feed cost over a year, saves labor costs otherwise needed for winter feeding, and provides a profitable way to recycle manure as a soil conditioner within fields. The protein-rich forage also slightly increased weight gain in cows. Millions of acres of grazing cropland in the Northern Great Plains are being degraded and not producing to capacity. Swath grazing that integrates crop, forage, and livestock components into an integrated system may contribute to more sustainable outcomes for landowners in the northern Great Plains.

Wheat growers are looking for ways to reduce herbicide use and livestock producers for ways to reduce feed costs. The largest use of herbicides in Montana, including the non-selective herbicide glyphosate, is for control of volunteer wheat during non crop fallow periods such as after harvest and during summer fallow. In collaboration with Montana State University, ARS scientists at Sidney, MT conducted a five-year study to evaluate and compare the effects of sheep grazing with chemical fallow and tilled fallow management systems on soil properties, weed community, and spring wheat yields. Grazing slightly reduced soil carbon and available nitrogen, phosphorus, and potassium contents, along with reduced soil pH, cation exchange capacity, and electrical conductivity due to reduced amounts of crop residue returned to the soil regardless if fields were tilled and not. Grazing, however, also increased soil calcium, magnesium, and sodium contents. Grazing had no effect on wheat grain and biomass yields, but reduced the need for herbicides by reducing populations of some problem weed species (Sainju et al 2010; Sainju et al 2011a; Sainju et al., 2011b). The study demonstrated that properly timed sheep grazing can be an effective way to economically control volunteer wheat and other weeds and sustain crop yields by reducing selection pressure for weed resistance to glyphosate, decreasing potential leaching of nitrates, and increasing nutrient cycling in soils.

Mixing cattle and crops can increase productivity, especially with conservation tillage. Integration of crop and livestock operations has the potential for solving many maladies facing modern agriculture by improving nutrient cycling, soil quality, and environmental quality, as well as diversifying farm income. Scientists at ARS in Watkinsville, GA conducted a field experiment during four years to determine (1) the impact of grazing cattle on crop production components, (2) the choice of tillage system on crop and cattle production, and (3) how tillage and cover crop management might impact economic return. Grazing of cover crops by cattle caused a slight reduction in corn grain yield, but had no effect on wheat grain yield compared to a system with unharvested cover crops (Franzluebbers and Stuedemann, 2007). Conservation tillage improved corn grain yield, produced greater cover crop biomass production, and contributed to greater cattle production than conventional-tillage management. Economic return followed the order: conservation tillage with grazing of cover crops > conventional tillage with grazing of cover crops > conservation or conventional tillage without grazing of cover crops. This study suggests there is great potential to improve farm-level economic stability and increase economic return on the existing 26 million acres of cropland in the southeastern United States by adopting conservation-tillage management and allowing cattle to graze cover crops.

Integration of crops and livestock could provide economic benefits to producers by intensifying land use and improving resource efficiency, but how this management might affect soil organic matter and its characteristics is not known. Scientists at ARS in Watkinsville, GA conducted a 3-year field experiment following termination of perennial pasture. Management systems evaluated were tillage (plow initially / disking thereafter and no tillage), cropping (sorghum or corn with rye as winter cover and winter wheat with pearl millet as summer cover), and cover cropping (grazed by cattle and left unharvested) (Franzluebbers and Stuedemann, 2008a). Tillage system had the most dominating influence on soil organic matter and microbial properties. If not tilled, soil organic matter remained very high near the soil surface and remained equivalent to long-term pasture. With plowing, soil organic matter was reduced in content due to greater decomposition. Cattle grazing cover crops did not have any major negative influences on soil organic matter, and sometimes even had positive influences on soil organic matter due to faster cycling of cover crop biomass to the soil through manure. Therefore, crop and cattle producers who adopt integrated crop-livestock systems are encouraged to utilize conservation tillage management techniques to help retain soil organic matter and build soil quality. This recommendation can be applicable to small- and medium-sized farms throughout the southeastern United States.

Specialization of crop and livestock operations in modern agriculture is common, but is not necessarily the most profitable, ethical, nor environmentally appropriate mode of agricultural production. There is a need to explore alternative production systems that might optimize production, profit, and environmental quality issues. An ARS scientist at Watkinsville, GA reviewed available literature to develop integrated crop-livestock production systems suitable for the southeastern United States (Franzluebbers, 2007). Rotation of crops with pasture could have benefits to both crop and livestock production systems. Growing crops in rotation with cover crops using conservation tillage would improve soil and environmental quality and increase income diversity and avoid risk, if cover crops could be grazed by cattle or other livestock. This review will assist scientists, extension specialists, and farmers to design and implement more robust agricultural systems to maintain high production, improve profit, spread investments costs across multiple operations, increase water and nutrient use efficiency, and improve environmental quality on the 100 million acres of farmland in the southeastern United States.

Although integrated crop-livestock systems have been employed globally for millennia, in the past century, farmers in North America have tended toward increased specialization. There is renewed interest in reintegrating crops and livestock because of concerns about natural resource degradation, the profitability and stability of farm income, long-term sustainability, and increased regulation of concentrated animal feeding operations. Scientists at ARS in St. Paul, MN and Watkinsville, GA collaborated with a scientist from University of Manitoba in Canada to review the scientific basis for integrated crop-livestock systems in North America (Russelle, et al., 2007). Integrated crop-livestock systems could foster diverse cropping systems, including the use of perennial and legume forages, which could be grown in selected areas of the landscape to achieve multiple environmental benefits. Integrated systems inherently would utilize animal manure, which enhances soil tilth, fertility, and carbon sequestration. Integration of crops and livestock could occur within a farm or among farms, although the complexity of such systems could constrain adoption. The combination of system complexity and potential for public benefit justify the establishment of a new national or international research initiative to overcome constraints and move North American agriculture toward greater profitability and sustainability.

Grazing of cover crops managed with conservation tillage may not be as detrimental to soil as often perceived. Integration of crops and livestock could provide economic benefits to producers by intensifying land use and improving resource efficiency, but how this management might affect soil compaction, water infiltration, and soil strength has not been well documented. Scientists at the USDA-ARS in Watkinsville, GA conducted a 3-year field experiment, whereby annual crops were grown following termination of perennial pasture (Franzluebbers and Stuedemann, 2008b). Conventional tillage loosened soil initially compared with no tillage, but the effect diminished with time. Grazing of cover crops had no effect on soil bulk density, perhaps because of the high soil organic matter content following perennial pasture that mitigated compaction. Soil aggregation was degraded by conventional tillage. Stability of soil aggregates was unaffected by grazing of cover crops in both tillage systems. Water infiltration was reduced with grazing of cover crops when soil water content was high. Soil strength was greater under no tillage than under conventional tillage. It was also greater under grazed than under ungrazed cover crops with conventional tillage, but not different between cover crop system with no tillage. Overall, the introduction of cattle to consume the high-quality cover crop forages did not cause substantial physical damage to the soil. Crop and cattle producers who adopt integrated crop-livestock systems are encouraged to utilize conservation tillage management techniques to help preserve surface soil organic matter and prevent deterioration of soil quality. This recommendation can be applicable to small- and medium-sized farms throughout the southeastern USA.

Niche Feedstock Sources for Bioenergy

U.S. corn, soybean, and wheat farms can benefit from having more crops to choose from to diversify crop risks and have alternative crops that provide new ways to control pests. Also, the United States buys about $1.5 billion worth of palm and coconut oils each year to meet half of its industrial needs for medium-chain-length fatty acids; the rest comes from petroleum. With commercial proven technologies available to produce renewable jet and other biofuels fuels from oil seed crops, there will be a greater demand for feedstocks to meet the needs of airlines, trucking industry, and the military who must rely on more energy dense fuels than ethanol. The demand for lipid-based feedstocks will continue to rise as renewable fuel production costs are reduced and these critical sectors seek dependable supplies of affordable fuels.

Eastern red cedar trees are native to the eastern half of the U.S., but have become an invasive species of formerly productive rangeland in the eastern Great Plains. In El Reno, OK, ARS researchers have worked with the Natural Resource Conservation Service's High Plains Resource Conservation and Development Council to turn this obstacle into a bioenergy opportunity. The team used remote sensing techniques to accurately estimate the amount of biomass that can be harvested and used to produce renewable energy. The research estimates more than 12 million tons of red cedar growing in 17 highly impacted Oklahoma counties – enough biomass to produce more than 800 million gallons of biofuel, or more than 9-million megawatt hours of electricity (Starks et al, 2011). This information is being used as a part of a business plan to build a commercial renewable fuel refinery in Enid, OK in 2012 that will sell the fuel to a commercial airline or the Defense Logistics Agency - Energy. ARS research is developing restoration scenarios for when after the red cedar is cleared to improve rangeland productivity for cattle grazing and restore native wildlife habitat. Long-term management strategies are needed to provide as many sources of revenue as possible to help make the price of renewable jet fuel competitive with petroleum-based fuel.

Researchers in Pullman, WA, showed that planting winter canola earlier allowed young canola shoots to become established and better survive the winter than typical times for planting. Canola also represents an alternative winter rotation crop to suppress annual weeds that are hard to control in wheat. This increase in establishment success means that farmers can use winter canola to help fend off weeds in their wheat fields that are planted the next season, and also reduce the amount of soil erosion during the winter and spring when fields would otherwise be bare and exposed to rain and melting snow. The Colville Confederated Tribes are working with ARS and Washington State University to find ways to take advantage of winter canola on tribal lands so they can extract canola seed oil to make biodiesel for their fleet of school buses and logging trucks. They also plan to sell meal from the crushed seeds to local farmers as a livestock feed supplement. In the future, as much as 20,000 acres of winter canola could be grown on Colville tribal lands. This acreage could support production of enough oilseeds for 2 million gallons of canola-based biodiesel and 6,500 tons of high-protein canola meal every year. These activities have the potential for generating annual gross revenue of $8.8 million for the tribe and the surrounding community (Young, 2011). The ARS research results have also been used by the USDA's Risk Management Agency as the basis for extending crop insurance for canola in two Washington State counties where the Tribe will obtain the needed canola seeds for biodiesel production. This research supports the EPA's in-progress review of the use of canola oil for biodiesel production to see if it meets requirements for greenhouse gas reduction under the Renewable Fuel Standard.

ARS scientists are looking for multiple oil seed crop options to increase income to farmers who grow corn, soybean, or wheat crops. Among these are *Cuphea*, a genus of flowering plants that produce oils similar to palm kernel and coconut oils that are produced commercially only in the Tropics and contain medium-chain-length fatty acids needed to make soaps, cosmetics, motor oils and other industrial lubricants, and hydraulic fluids. Researchers in Morris, MN and Peoria, IL have worked closely with public and private partners including the Procter & Gamble Company of Cincinnati, OH to find genetic lines more suitable for processing. In addition to its industrial usefulness, *Cuphea* can serve as an alternative to soy, sunflower, or canola as a biofuel source and some species that are particularly well suited as feedstock for manufacturing aircraft fuel, grow quite well in the upper Midwest (Gesch et al, 2010). Furthermore, when rotated with corn, soybean, and wheat in the northern Corn Belt region, *Cuphea* provides benefits such as increased seedling emergence and higher grain protein content in spring wheat when following *Cuphea* in rotation (Gesch et al., 2010). ARS produced a set of farming practices and farmers' guide to growing *Cuphea* in cooperation with farmers who agreed to test the crop. Technology Crops International, a seed company in Winston-Salem, North Carolina, distributes the guide and seeds to farmers who grow *Cuphea* under contract. Several herbicides common to Midwest farmers can be used to control weeds in *Cuphea*, whose seedlings develop slowly and are highly susceptible to weed competition (Forcella et al., 2011).

Also, mustard crops such as camelina, lesquerella, pennycress, and canola are also being investigated for their potential as seed oil crops for biofuel and other industrial products. Scientists in Peoria, IL and Morris, MN are finding the best ways to grow pennycress and camelina as winter annual crops, followed by soybean as a summer crop in order to provide both a fuel and food crop in a single growing season – from the same land. Camelina, grown as a winter annual in the upper Midwest potentially provides important environmental benefits as a cover crop, such as reducing erosion and taking up excess soil nitrogen, while it also provides farmers with a new source of income as a biofuel feedstock. Moreover, agricultural inputs for winter camelina production are relatively low and it does an excellent job of suppressing early summer weed growth (Gesch and Cermak, 2011).

In addition to finding out how well these crops yield under different production and environmental conditions, ARS scientists in Peoria are also analyzing oil quality in a pilot commercial-scale plant that has processed barrels of oil from camelina, canola, *Cuphea*, lesquerella, meadowfoam, milkweed, mustard greens *(Brassica juncea),* pennycress, soybean, and sunflower. Scientists in Maricopa, Arizona are developing production practices and new lines of lesquerella for production in the arid southwest. Lesquerella produces an oil similar to castor oil which is currently all imported. Lesquerella oil has been shown by ARS scientists at Peoria and Maricopa to be an excellent replacement for castor oil in lubricants and for use as a diesel fuel additive to improve the performance of other oils used for bio-diesel fuel. Maricopa scientists are evaluating camelina germplasm for early maturing lines that can be used in rotation with cotton (Yao, 2010). Camelina is a low water use crop that could be grown in the winter between cotton crops to reduce dust pollution from fallow lands and provide seed oil that can be used for jet fuel. The Southwest USA is advantageously located close to several major military bases and pipelines that can use biofuels produced locally.

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INTEGRATED TECHNOLOGY AND INFORMATION TO INCREASE CUSTOMER PROBLEM SOLVING CAPACITY

This component of the Action Plan focuses on the development and use of technology to increase production system efficiency by customers and stakeholders. ARS customers not only want the latest information and best technology research can provide, they also want to know how to incorporate these innovations into their operations. Also critically important is whether the new technology will increase their ability to compete in the market. Understanding the system level impacts of implementing new technology increases adoption and reduces uncertainty and risk. Recognizing that users are the ultimate system integrators, customer participation in the research process is necessary for the successful transfer and adoption of these new technologies.

New production technologies

In the upper Midwest, ARS scientists documented the use of multi-crop rotations as an improved conservation practice for producers. The four year rotation of corn-soybean-wheat/alfalfa-alfalfa, included reduced tillage management, and reduced agrichemical inputs. That research conducted in the upper Midwest improved soil fertility including nitrogen (N) availability and increased soil carbon (C). In addition, the grains nutrient composition and in many cases overall yields were increased with these new rotation methods (Gesch et al., 2010). This research should enable greater use of conservation practices by upper Midwest farmers. Doing so would increase the economic sustainability of their farming systems and result in significant environmental benefits.

At Sidney MT, researchers identified annual forages as profitable alternatives to summer fallow in semi-arid dryland farming operations. Economic forces are driving the replacement of wheat-summer fallow cropping systems by diversified, continuous cropping systems in dryland crop production areas of the semi-arid Northern Great Plains, but results are quite variable and growers lack direction. ARS scientists at Sidney, MT have determined that annual spring-seeded forage crops use less water than cereal grains, including durum, and may be a suitable replacement option to summer fallow. A five year experiment compared yield, quality, and water and nitrogen use of durum-fallow rotations with two-year rotations of continuous durum and three annual forages: forage barley, forage barley interseeded with field pea, and foxtail millet. Averaged over years, preplant soil water and residual N content were greater for durum following fallow than for durum following annual forages, resulting in reduced total fertilizer N requirement and greater yield, water use, grain N accumulation and N recovery index (NRI) following fallow. In addition, replacing summer fallow with annual forages reduced durum grain yield by 10.8 bushel per acre. But while those factors appear to favor the wheat-fallow system, forage yields of nearly 2.5 tons per acre produced a higher annualized return over the five-year study period for all three wheat-forage rotations, greatly reduced herbicide use and substantially lowered total fertilization costs, despite reduced wheat yields. Under the study, the annualized net returns in the three annual forage-durum systems were $51 per acre, $31 and $14 per acre greater than for fallow-durum, respectively (Lenssen and Cash, 2011). This information will be useful in making cropping system decisions in the Northern Great Plains.

Scientists at the Northern Plains Agricultural Research Laboratory at Sidney, MT completed a 21-year study of the long term effects of tillage and cropping sequence on soils and economic sustainability. Crop biomass was 53 to 66% greater with reduced tillage with an annual cropping system than for conventional till with spring wheat followed by a fallow system. Even though less wheat was produced each year with the annual crop system, total income over the two years was greater than for the one crop produced every other year. Just as important, the amounts of C and N in the soil surface residues were 23 to 141% greater than in the conventional system (Sainju et al., 2009).

Irrigation technology and site-specific precision agriculture

To fully realize the benefits from irrigation, frequent and accurate updates of soil moisture conditions across a farm are needed to time water applications. ARS researchers in Stoneville, MS have developed an integrated data collection system that greatly reduces the amount of labor needed to collect field soil moisture data information in the field to make accurate irrigation scheduling decisions. The automated system was a useful tool for production-scale soil moisture monitoring. By scheduling irrigation using the microcontrollers, water use was reduced in one study 25%. For a 12,000 acre farm, one irrigation scheduling operator can remotely accomplish in one hour what would take a week to collect manually. Moreover, the near-continuous recordings with the automated system allow researchers to monitor soil moisture changes throughout the day. This enhances daily irrigation scheduling accuracy (Sassenrath et al., 2010a). Combining new monitoring technology with crop-based irrigation scheduling models help farmers improve crop performance, reduce production costs, and labor costs, and conserves water resources.

At Sidney MT, a wireless sensor-based system was developed to save water and minimize agrichemical leaching to groundwater. The Northern Plains Agricultural Research Laboratory at Sidney, MT incorporated an in-field wireless sensor network to control variable-rate irrigation for on-farm use (Evans et al., 2010; Kim and Evans 2009; Kim et al., 2009). Sprinkler nozzles were controlled wirelessly based on real-time information feedback of a crops soil-water status. This technology helps growers remotely access field conditions in real-time and provides control of site-specific irrigation. The technology helps to ensure correct and precise water application at the right time and with the right amount.

In another “site specific “precision agriculture study, scientist at Pendleton, OR developed a low cost “Trigger-on indicator” for a weed sensing spray unit**.** A major drawback with intermittent precision application spray systems is that they don't provide feedback to the user when one of the spray units is actively spraying. This limitation makes it difficult to determine if the sensors are functioning properly, particularly on wide boom spray units. To overcome this, ARS Scientists at the Columbia Plateau

Conservation Research Center in Pendleton, OR developed a low cost trigger-on indicator that provides visual feedback to the operator (Siemens et al., 2007). The device performed reliably over a 150-hr test period. This development will help speed the adoption of herbicide reducing intermittent spray systems on large acreage farms.

Simulation modeling and large on farm data sets to improve agricultural sustainability

A significant societal challenge we face is finding ways to meet the conflicting interests of industry, environmental groups, and policy makers. ARS scientists in Corvallis, OR have developed a way to choose the best agricultural production system to meet the needs of different stakeholders. A new model called PGA-BIOECON simultaneously evaluates the tradeoffs among production efficiency, profitability, and natural resources quality objectives (Whittaker et al., 2007). Thus farmers, conservationists, and policy makers can use the model to simultaneously evaluate what is important to them, and see how it affects others. If a person values water quality more than farm profit, they may choose differently than someone who values profit only. With PGA-BIOECON, the best scientific and economic information are provided about trade-offs, so the most informed choices can be made. Answers to these kinds of questions are critically important to our country's agricultural systems and farmers who must finds ways to sustainably produce food fiber and energy while maintaining the quality of air soil and waters.

In another simulation modeling effort, ARS scientists tested and improved the soybean model GLYCIM for its performance under a range of conditions around the world (Lokhande, et al., 2009). In the process, they've pinpointed the best agronomic practices for maximizing soybean production in Thailand. GLYCIM was designed to simulate soybean growth for any cultivar, as affected by variable soils, climate, and season. ARS scientists at the Crop Systems and Global Change Laboratory in Beltsville, MD, partnered with scientists at the Asian Institute of Technology in Pathumthani, Thailand, to see how well GLYCIM estimated actual soybean yields in Thailand. The team calibrated GLYCIM using data from a soybean field study conducted in Thailand that tracked soybean growth and yield. Then they simulated soybean yields under variable weather, seven planting dates, on three soil types and with three soybean cultivars. This resulted in the development of 252 different cultivation and yield scenarios for each of two key soybean production areas in northern Thailand. GLYCIM results indicated that it is critical for farmers to use optimal planting dates to achieve high yields at these sites. Planting on May 2 and May 16 produced the greatest yields, while earlier planting resulted in yields ranging from 7% to 17% less. Yield losses in delayed planting simulations averaged around 30%. GLYCIM can help Thai farmers identify the best dates and soybean cultivars to obtain the highest yields, which could help increase production to meet current and future demand. Farmers in Thailand and other tropical regions could also use GLYCIM to estimate how management practices could be adjusted as the global climate changes and with variable weather patterns.

Scientists in Beltsville, MD developed, tested and improved a mathematical model of photosynthesis for potato that is responsive to sunlight, temperature, and atmospheric carbon dioxide. Mathematical crop models have been developed over the past forty years for farm management and crop inventory tools. Despite significant improvements, the models still need to incorporate the effects of increased atmospheric carbon dioxide associated with potential climate change on plant growth. The improved photosynthesis model was merged with other recent research results into a new potato growth simulation model (SPUDSIM) and tested over a wide range of conditions with good results (Fleisher et al., 2010). The increased accuracy of the model will enable producers to better manage potato production, and will enable scientists and policy-makers to make better assessments of food production under conditions of changing climate.

In another effort with potato a model was developed for predicting Late Blight on Potato tubers. Late Blight accounts for significant losses of potato in both field and storage environments; however, few models are currently available for predicting Late Blight on tubers. ARS scientists at Orono, ME evaluated a tuber blight prediction model, developed in New York, with weather and plant growth data from a field site (Olyana et al., 2010). The model correctly predicted tuber blight incidence in 7 out of 9 years. This has the potential to improve the accuracy of Late Blight prediction on potato tubers, thereby enhancing disease management in both field and storage environments.

Scientists at Fort Collins, Colorado used the iFARM Field Economic Assessment Tool (iFEAT) and the whole-farm GPFARM model to perform cost-benefit analysis for alternative crop management of farming systems in the northern Great Plains region (Palic et al., 2008). The scenarios included crop rotations, crop insurance options, and land lease arrangements that were run with variable commodity prices. Increased net return to the producer was the objective of the analysis. Two crop insurance options were used, along with two crop share and land rental lease arrangements. Also included in the analysis was a farmer owned non-lease arrangement. Commodity prices ranged from the 2006 average, to the much higher averages common in 2007 and 2008. With the lower 2006 commodity prices, the 60/40 crop-share lease with production costs split equally between tenant and land provided the most equitable split between tenant and owner. The cash lease option produced the smallest net return to the grower. With elevated commodity prices (2007/2008), the cash lease option was more profitable for the tenant than the 60/40 split. This held true even with a significantly higher rental price. Results of this kind of analysis are being prepared as a fact sheet to help farmers decide which production options are best for their conditions during these times when production costs and prices are highly volatile.

Projecting the effects of climate change on wheat production is necessary for quantifying potential food security issues of the future. ARS Researchers at Fort Collins, CO used Root Zone Water Quality Model 2, after first calibrating with a FACE (Free Air CO_2 Enrichment) experiment in Maricopa, AZ, under two irrigation and two N treatments, and were able to reproduce the CO_2 effects on spring wheat production under all treatments (Ko et al., 2010). Model simulation using projected climate conditions showed that the effects of high CO_2 and increasing temperature on crop yield partially cancelled each other. An analysis of the output also suggests that irrigation and N management might have greater effects on crop yield than potential climate changes in the next 10 years.

New crops in Root Zone Water Quality Model 2 (RZWQM2) model. Canola has been increasingly important as an alternate crop in rotations with wheat due to its potential bio-energy use. ARS researchers at Fort Collins, CO, used RZWQM2 to simulate canola production under different cropping systems (Saseendran et al., 2010). Results indicate that the canola model is sufficient for predicting canola production under semi-arid conditions. The new model component will help extend current canola study in the Great Plains.

Increasingly sophisticated computer models allow for assessments of the impacts of soil, water and energy conservation and new production methods on the sustainability of various cropping systems. But these assessments are only as good as the tools used to measure the many variables involved. Crop residue cover, a key indicator of soil carbon storage and soil conservation benefits, is one such variable that has previously been highly labor intensive and expensive to accurately calculate. To address that issue, ARS scientists at Sidney, MT in collaboration with researchers at the ARS Hydrology and Remote Sensing Laboratory, Beltsville, MD, and with ARS researchers at Sidney, MT and Akron, CO, Pendleton, OR and Pullman, WA examined use of the remotely-sensed cellulose absorption index (CAI) to evaluate crop residue cover and the subsequent sustainability of various cropping systems in semi-arid regions (Aguilar et al., 2011). Scientists determined that CAI could be used to provide reliable estimates of crop residue cover in these semi-arid dryland regions, which can, in turn, be utilized in computer models to help determine the sustainability of different cropping systems in these regions. In addition, in collaboration with scientists at the Livestock and Range Research Laboratory in Miles City, MT, the technique has also been shown to successfully assess residue cover and subsequent “fuel loads” for computer models looking at wildfire potential of rangelands. The technique also holds potential for many other computer model applications looking at carbon sequestration and to aid compliance with government farm conservation programs. The method is an affordable, reliable remote sensing technique that is now verified for use in computer models of agricultural systems.

While no-till and minimum tillage systems provide environmental benefits, use of these practices for corn and soybean production in the northern Corn Belt has been limited because farmers believe they are less profitable than conventional tillage practices. In a 7-year field study in Morris, MN, ARS scientists compared the economics of eight different tillage practices (Archer and Reicosky, 2009). Switching from moldboard plow tillage to a minimum tillage fall residue management system increased average net returns by as much as $37 per acre. Furthermore, all but one of the minimum tillage and no-till systems evaluated were less risky than the two conventional tillage systems commonly used. This research could enable greater adoption of minimum tillage and no-till systems in the northern Corn Belt.

ARS scientists in Pendleton, OR in cooperation with ARS scientists in Beltsville, MD developed a new spectral vegetation index sensitive to plant chlorophyll content. Plant chlorophyll content is a useful indicator of N fertilizer need (Eitel, et al., 2008). However, the index is also sensitive to crop cover variability across fields; which are often the result of soil moisture differences. The new ARS index improves our ability to use remote sensing to precision-apply late-season N fertilizer based on crop need, regardless of how soil moisture affects crop growth. This is important for wheat grown in semiarid regions where spectral reflectance can be dominated by soil moisture variability. In arid regions, N fertilizer is applied late in the growing season to boost grain quality before harvest. Precision applications of fertilizer to match crop needs across a variable field can save input costs and reduce the chance for potential negative environmental impacts of excess nutrient loading. This research is a part of an expanded effort for precision management of N application in wheat based production systems across the U.S. A. The effort is coordinated among ARS projects at Pendleton, OR, Sidney, MT, and Hydrology-Remote Sensing Laboratory at Beltsville, MD. The effort is providing ground-based validation data for larger scale regional models. Production system information is being used to validate the Fort Collins, CO Root Zone Water Quality Model-2 (RZWQ2) across temporal and spatial scales.

ARS scientists in Corvallis, OR used an extensive ground-based survey of the different agricultural management practices used to grow crops across the Calapooia River watershed. They used the results to validate a remote sensing approach (using satellite images) to distinguish crops and management used by farmers. The survey incorporated input from field locations and management practices used for three years into a Geographic Information System (GIS) database. The information collected and modeled for the individual fields, were used to train the classification of a series of commercially available Landsat satellite images comprising over 90% of all land use practices. These results were then used to calibrate a simulation model: the Soil Water Assessment Tool (SWAT). SWAT is an ARS model used to assess natural resources conditions that result from variable land management practices (Colvin et al., 2008). This effort will enable the use of satellite images across watersheds as model input data. The model can then be used to develop recommendations for the best combination of cropping practices that optimize profitability yet minimize negative environmental impacts of farm management.

If agriculture is to be sustainable, it is critical to understand how it is affected by social and political factors. A panel of experts was surveyed to identify the most important social and political influences on U.S. agriculture. Although the panelists often had contrasting views about the importance of some factors, there was strong agreement that globalization and narrow or low profit margins requiring increased scale and efficiency were the two most important factors affecting agriculture (Archer et al., 2008). This research provides agricultural scientists with a better understanding of the social and political effects on agriculture resulting in the development of agricultural systems more likely to be accepted and used by farmers. This research also provides information needed by social scientists and policy makers to develop policies that lead to more sustainable agricultural systems.

To enhance the sustainability of agricultural systems, researchers need to understand how and why producers make decisions. Understanding these decision-making processes allow researchers to develop agricultural systems that address producer concerns and tailor the way the technology and management systems are delivered to producers increasing the likelihood of adoption. ARS researchers in Mandan, ND; Stoneville, MS; Orono, ME; Madison, WI; and Pullman, WA developed a series of workshops using producer focused panels to investigate the decision making process for integrated agricultural producers. The first workshop was held in Mandan and resulted in four major categories of drivers for integrated agricultural systems (Hendrickson et al., 2008a,b,c; Archer et al., 2008; Hanson et al., 2008; Sassenrath et al., 2008; Halloran and Archer, 2008). Subsequent workshops in Auburn, AL, Orono, ME, Madison, WI and Pullman, WA revealed that farming lifestyle was the principle driver that led people to choose farming as a career (Sassenrath et al., 2010b), but there were regional differences in economic and social interactions between farmers and consumers evident in marketing channels used by producers (Halloran et al., 2011 and Sassenrath et al., 2009).

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Appendix A: List of NP-216 projects

Project Number	Project Title	SY	City	State	Lead Scientist
1265-21660-003-00D	Principles and practices for improving organic farming in the mid-Atlantic region	4.8	Beltsville	MD	Cavigelli
1265-61660-006-00D	Mechanistic process-level crop simulation models for assessment of agricultural systems	3	Beltsville	MD	Timlin
1915-62660-002-00D	Enhancing sustainability of food production systems in the northeast	6.6	Orono	ME	Vacant
3625-21610-001-00D	Enhanced Midwestern cropping systems for sustainability and environmental quality	3.15	Ames	IA	Singer
3645-61660-002-00D	Multi-scale evaluation of land use management systems in the upper Midwest	1.6	Morris	MN	Jaradat
5305-21620-012-00D	Strategies to improve soil and pest management in organic vegetable production systems	1	Salinas	CA	Brennan
5348-21610-001-00D	Increasing inland pacific northwest wheat production profitability	1.3	Pullman	WA	Young
5354-21660-002-00D	Sustainable cropping systems for irrigated specialty crops and biofuels	2.75	Prosser	WA	Collins
5356-21610-001-00D	Increasing inland pacific northwest wheat production profitability	2.4	Pendleton	OR	Long

PROJECT NUMBER	Project title	SY	City	State	Lead Scientist
5358-21410-003-00D	Production and conservation practices to maintain grass seed farm profits	4.5	Corvallis	OR	Griffith
5402-61660-006-00D	Enhanced system models and decision support tools to optimize water limited agriculture	2.75	Ft Collins	CO	Ma
5436-13210-005-00D	Ecologically-sound pest, water and soil management strategies for Northern Great Plains cropping systems	8	Sidney	MT	Evans
5445-21660-002-00D	Integrated agricultural systems for the northern great plains	4.15	Mandan	ND	Hendrickson
6227-21660-003-00D	Economic and environmental benefits from multiuse agricultural landscapes to family farms	2.1	Booneville	AR	Burner
6402-12130-003-00D	Development of sustainable production systems and water management technology for the mid south	1	Stoneville	MS	Sassenrath
6406-21610-009-00D	Development of precision agriculture systems in cotton production	2.8	Mississippi State	MS	Jenkins
6420-12610-004-00D	Conservation systems research for improving environmental quality and producer profitability	6.4	Auburn	AL	Balkcom

PROJECT NUMBER	Project title	SY	City	State	Lead Scientist
6604-64000-007-00D	Sustaining peanut cropping systems competitiveness	0.8	Dawson	GA	Lamb
6612-11120-004-00D	Soil organic matter and nutrient cycling to sustain agriculture in the southeastern USA	1.3	Athens	GA	Franzluebbers
6612-61660-002-00D	Improving crop and animal production systems for southern producers	3.5	Athens	GA	Schomberg

Appendix B

NP 216 Publications

Abou-Najm, M., Jabro, J.D., Iversen, W.M., Mohtar, R., Evans, R.G. 2010. New Method for the Characterization of 3D Preferential Flow Paths at the Field. Water Resources Research. VOL. 46, W02503, doi:10.1029/2009WR008594.

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