Accomplishment Report
(2002-2006)

National Program 207, Integrated Agricultural Systems
Agricultural Research Service
U.S. Department of Agriculture

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Introduction

National Program 207, Integrated Agricultural Systems

Participants at many USDA-ARS Customer Workshops have expressed the need for multidisciplinary systems research solutions to their problems. The meeting of this need was formally put into place with holding the USDA-ARS NP-207 Customer Workshop December 7-9, 1999 in Denver, Colorado. A range of customers and partners participated, including conventional and organic farmers, members of commodity organizations, USDA-NRCS, tribal representatives, farm equipment manufacturers, fertilizer dealers, and various advocacy groups, including the Sustainable Agriculture Coalition and Center for Rural Affairs.

The primary customer outcome from the Denver workshop was a list of specific attributes that ARS research should include when conducting integrated agricultural systems research. In brief, a philosophy for conducting research was outlined. Among the distinguishing features integrated agricultural systems research should emphasize were:

- Stakeholders should participate in the research process from project design to completion,
- On-farm research approaches should be preferred over experiment station plots,
- A spectrum of agricultural approaches, management strategies, and philosophies should be included in the research,
- Multiple factors should be considered at the same time,
- Agricultural production should be viewed within a larger holistic system that also includes environmental, economic, and sociological components,
- Information transfer should be facilitated through regular interactions of the researchers with customers and stakeholders,
- Experiments should be conducted at scales greater than traditional projects,
- Information should be incorporated from other National Programs that were perceived to not use systems approaches, and
- Research results should be transferred by the researchers to clients, partners, and stakeholders to ensure relevant progress.

The resulting NP-207 Action Plan from the workshop input did not provide a specific research project outline, as found with the other ARS National Programs, but gave a few examples of systems research projects. In retrospect, this was a significant short-coming of the program planning process. However, structure was provided by way of recognized research components that have been regularly presented in the NP-207 Annual Reports. These have included: Cropping Systems, Integrated Crop-Livestock Systems, Site Specific Management and Precision Agriculture, and Decision Support Systems. The final organization of this Accomplishment Report is arranged around general classes to which the accomplishments are categorized based loosely on specific USDA Strategic Goals. Supporting the accomplishment statement was a listing of refereed publications accepted since 2002, and listings of proceedings papers, technical notes, and extension bulletins, reports in the popular press, or other notable records of the research.

RESEARCH GOAL I. ENHANCED CAPACITY TO SOLVE PROBLEMS USING SYSTEM RESEARCH APPROACHES.

Accomplishments were provided by 23 research projects classified as NP-207. The total annual budget for these projects is approximately $28.7-million. There are approximately 60.5 Scientist Years assigned to NP-207 projects. More than 115 accomplishments were compiled and analyzed for this accomplishment report. The research activities were reported for the five-year period 2002-2006 (less than 60 months because of the accelerated review cycle to coincide the next five-year review with NP-205, Rangeland, Pasture, and Forages), and represent a broad range of activities over a wide geographical area (Table 1).

Table 1. List of 24 contributing locations to the NP-207 Accomplishment Report.

Ames, IA	Mandan, ND*	
Auburn, AL*	Madison, WI	
Beaver, WV	Mississippi State, MS	
Beltsville, MD	Morris, MN	
Booneville, AR	Orono, ME	
Brookings, SD	Prosser, WA	
Columbia, MO	Pullman, WA	
Corvallis, OR	Salinas, CA	
Dawson, GA	Stoneville, MS	
Florence, SC*	Sidney, MT	
Fort Collins, CO	Watkinsville, GA	
Lane, OK*	Weslaco, TX	* not NP-207

A. Problem Area. Systems Research Attributes Assessment. This portion of the report is based on the Systems Research Attributes template that was used to evaluate each accomplishment provided by the field. The attributes were based on the research criteria that were given by the customers at the NP-207 Workshop. The results for all accomplishments are given in Appendix 1.

1. Customer Involvement. Stakeholders have provided great amounts of guidance for the research conducted to achieve the accomplishments reported by NP-207. More than 81% of all accomplishments indicated that customers were involved with the initial problem assessment, and approximately 80% of all accomplishments reported an ongoing involvement with customers and stakeholders. These large percentages demonstrate the commitment of NP-207 scientists towards this value that was identified by customers at the first National Program Workshop. Customer involvement helps to ensure that NP-207 research is appropriately targeted toward problems that will benefit customers and stakeholders.

2. Research Approach. Even though NP-207 was formally first recognized as a National Program in 2002, a systems approach to research projects was already underway at many of the locations involved in this National Program. A majority of accomplishments (54%) reported their projects were based on maturing research studies between 5-10 years old (Figure 2). Shorter-term experiments or new systems projects that were begun less than five years ago contributed to 29% of the accomplishments reported. Seventeen-percent of the projects had been underway for more than 10 years.

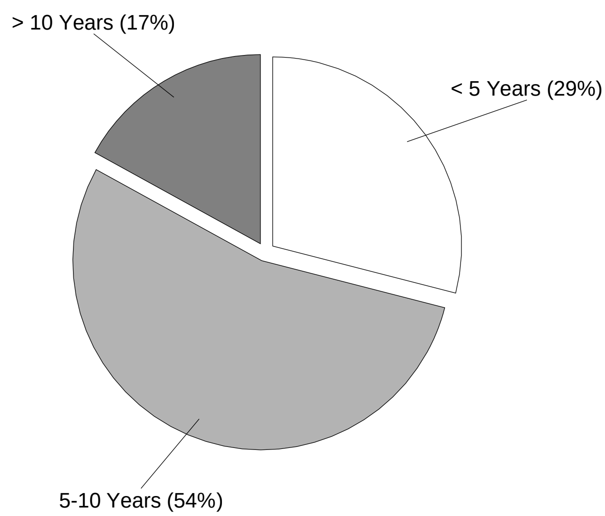

Figure 1. Percentage of NP-207 accomplishments that were found from research on short-term (0-4 years), maturing (5-10 years), and long-term (>10 years) studies.

Small plot research contributed to the largest percentage of research accomplishments (60%), with full-scale commercial equipment being used for 57% of the research activities. Large landscape or field-scale research was also a significant contributor to the accomplishments, being responsible for 25% of the findings. Also, most accomplishments reported contributions from on-farm experiments (60%). Multiple-location experiments were conducted for more than 71% of all accomplishments (Fig. 3). Most accomplishments utilized less than 20 research sites, but a few used large numbers of sites, with as many as 80 and 150 different sites.

The research teams that conducted the research and reported the accomplishments were achieved mostly with multidisciplinary teams of scientists and cooperators (88%) that often included non-ARS members (82%). More than 46% of the accomplishments had team members from multiple ARS locations. A large majority (84%) of the accomplishments had multiple experimental factors in their project descriptions.

3. Measured Assessments. These metrics address multiple dimensions of the agricultural issues, farm and natural resources impacted, and the context of the research.

Most research accomplished under NP-207 reported that their emphasis was on improving production practices (83%), as opposed to improving product quality (39%). Additionally, the majority of accomplishments were categorized as having economic (77%) or environmental (50%) implications, as opposed to having social impact (15%). The three most prominent natural resources concerns addressed by NP-207 research were soil (77%), water (68%), and plant (55%), with air quality (17%) and wildlife (9%) addressed to a lesser extent (Fig. 4).

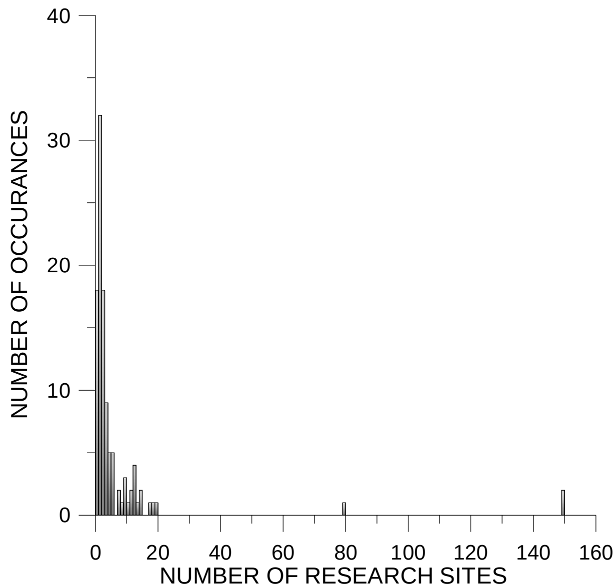

Figure 2. Histogram of the number of research sites used for each accomplishment reported.

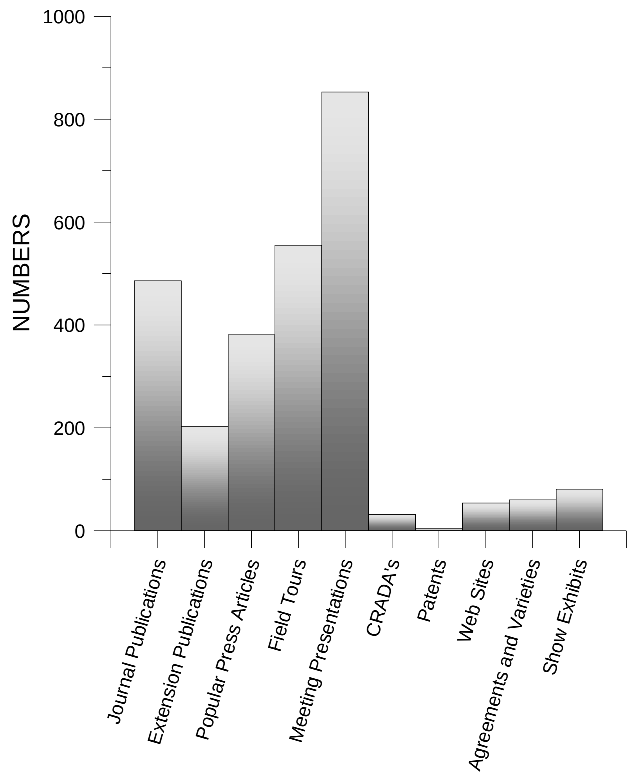

Figure 3. Percentage of accomplishments that was associated with a specific natural resource. Broad natural resources categories are based on the USDA-NRCS Conservation Planning and Physical Effects framework (SWAPA+H).

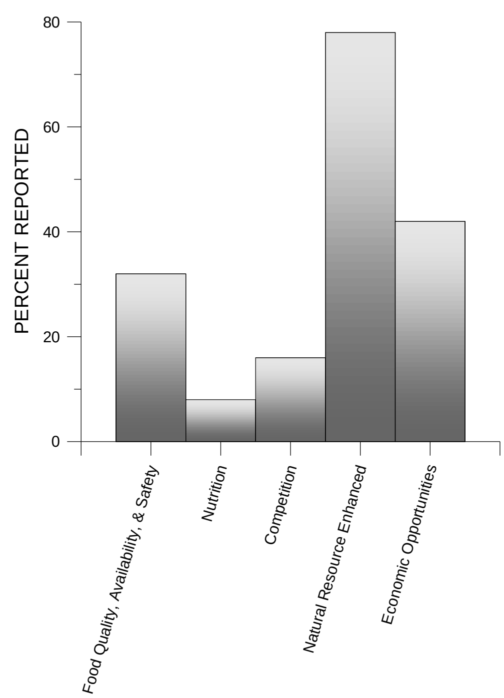

Figure 4. Percentage of accomplishments that was associated with USDA-ARS areas of mission relevance.

When asked to assess the USDA-ARS mission area relevance (Fig. 5), most scientists chose natural resources enhanced (78%). Economic opportunities (42%) and food quality, availability and safety (32%) were the next two selections. Enhanced competition (16%) and nutrition (8%) were the least associated areas of mission relevance for the NP-207 accomplishments.

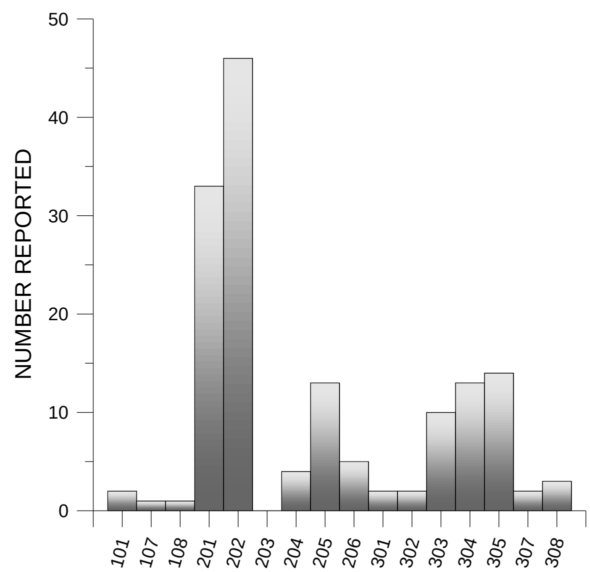

Figure 5. Number of accomplishments that identified other associated National Programs as being relevent to the NP-207 research. A listing of National Program numbers can be found on the Web at: http://www.ars.usda.gov/main/main.htm

Only 19% of the accomplishments reported that NP-207 was the only National Program to which researchers belonged. The other 81% chose at least one additional National Program as being germane. ARS National Programs 201 and 202 (also in Natural Resources and Sustainable Agricultural Systems) were the two most common programs that were mentioned as being relevant to the NP-207 accomplishments (Fig. 6), with numerous others being mentioned less frequently.

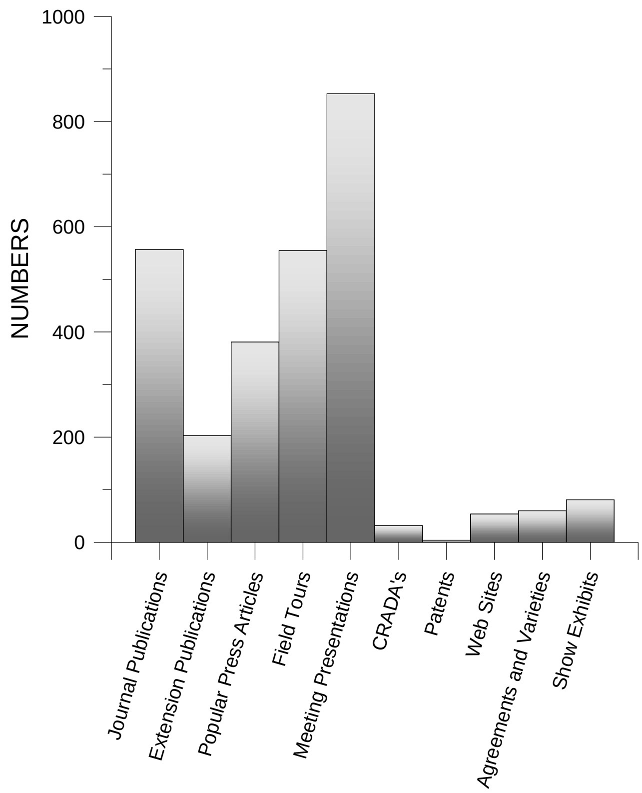

Figure 6. Total number of publications and technology transfer activities reported by the NP-207 accomplishments.

B. Problem Area. Research Impact Assessment. This portion of the report is based on the Systems Research Impact template that was used to evaluate each accomplishment provided by the field. The metrics used to assess impact represent a wide range of features that include technology transfer, acreage and finances affected, and influence on policies. The results of all accomplishments are given in Appendix 2.

1. Technology Transfer. The scientists within NP-207 published a total of 493 refereed journal publications and 203 extension publications (Fig. 6). This is an average of 2.2 journal publications and 0.9 extension publications per accomplishment. A total of 381 popular press articles were written about the NP-207 accomplishments, or almost 1.7 articles per accomplishment. Four patents resulted from technology developed by this national program. A significant amount of effort was dedicated to communicating research results directly to stakeholders through 555 field tours, 853 meeting presentations, and 81 trade show exhibits. A great amount of cooperation with private industry was also found with 32 cooperative research and development agreements, 81 technology and materials transfer agreements, and varieties released. The Internet was also used as a vehicle to communicate results to stakeholders, with 54 web sites being updated on a regular basis with new research information.

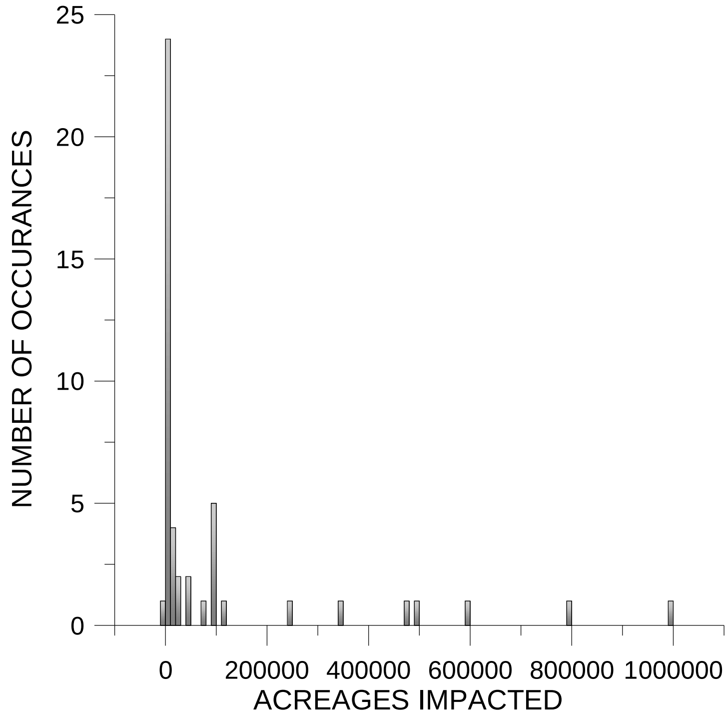

Figure 7. Histogram of the acreages impacted by NP-207 accomplishments.

2. Impact of research on farm income. Almost four-million acres of farmland were reported to be impacted by research from this National Program with results being readily adopted. These enterprises range from small farms involving organic production to large acreages where significant portions of regions have modified their production system (Fig. 8). Benefits to stakeholders vary from reduced impediments and expenses to increased amounts of revenue. Examples of impediments mitigated were reduced soil loss to erosion, reduced soil borne disease, reduced weed seed production, reduced need for pesticides, reduced nitrogen and phosphorous loss, reduced fuel use for tillage and grain drying, reduced labor costs, and increased carbon storage in the soil.

Most accomplishments resulted in decreased producer expenses that ranged from as small as $4 per acre for improved cotton field scouting methods, to as much as $675 per acre for use of alternative management practices that replaced methyl bromide use. Improved revenues ranged from $3 per acre for alternative methods of terminating cover crops, to $10,000 per acre for adoption of high-value specialty crop production. Using researcher estimates for accomplishments that have been currently adopted suggest that NP-207 research has increased income to American producers $56-162 million per year. These rough estimates do not include future production costs savings or increased revenues from the impact of accomplishments that are just beginning to be adopted.

3. Quality of Research Outcome. Stakeholder satisfaction was positive, with 63% of all accomplishments reporting that producers' initial concerns about a problem had been met. To a lesser degree (36%), the general public was also deemed satisfied by the accomplishment outcome. Only 13% of all accomplishment results were used to demonstrate some form of regulatory compliance. Worker satisfaction was largely not addressed by this national program, with less than 2% reporting this as an issue.

4. Impact on Policies or Competitiveness in the Market. A notable weakness is the lack of accomplishment results being passed on to USDA-NRCS in support of USDA Farm Bill Conservation Title, with only 13% reporting their research results help customers increase access to these programs. However, this program has great potential for impacting future Farm Bill Programs through expanded relationships with USDA-NRCS and USDA-FSA.

Some accomplishments (18%) reported that their results had been used to change current local, state or national policies. The competitiveness of local customers participating in U.S. agriculture was reported to be improved by NP-207 accomplishments, with more than half (52%) reporting that unique products, processes, systems, or services had been produced. The amount of agricultural product made available was increased by 29% of the accomplishments, and the local community economy was positively impacted by 24% of the accomplishments.

RESEARCH GOAL II. ENHANCED ECONOMIC OPPORTUNITIES FOR AGRICULTURAL PRODUCERS AND RURAL COMMUNITIES.

Problem Area A. Strategies to Reduce Production Costs and Increase Profit.

1. Conservation Tillage. Conservation tillage has several attributes that can reduce the risk associated with agricultural production. For example, conservation tillage can increase crop productivity through reduced soil loss, and increased organic matter and soil moisture. Conservation tillage can also reduce production costs, thus increasing profitability. The combination of increased productivity and reduced costs can further increase profitability and reduce economic risk. In a few cases, these accomplishments could have been listed under other problem areas, but in these cases conservation tillage was a key to success. Researchers have also been successful in extending this technology to their stakeholders.

Expansion of conservation systems research project leads to technology transfer initiatives. As a result of a customer focus group meeting in 1999, rapid expansion of the Conservation Systems Research Project has led to increased research and technology transfer activities throughout the Southeastern U.S. Five new multi-disciplinary scientists (agricultural engineer, agricultural economist, agronomist, soil scientist, and weed scientist) and supporting technicians were hired to conduct research that seeks to increase adoption of conservation tillage systems throughout the region. Additionally, specific cooperative agreements with other institutions have resulted in new research and technology transfer thrusts that focus on increased use of soil testing, site-specific agriculture programming, small farmer conservation tillage assistance, and the long-term use of reduced tillage and poultry waste as a nitrogen source in conservation tillage systems. Results of this project have currently been seen with the percent adoption of conservation tillage systems increasing rapidly in Alabama, with 48% of the cropland being managed with conservation tillage systems. This number has increased dramatically since 1990 when the adoption rate was 15%, and has now surpassed the 41% national and 28% regional averages. **ARS Locations and Cooperators:** Auburn, Watkinsville, Alabama Farmers Federation, Alabama Cooperative Extension Service, NRCS. Auburn University, Alabama A&M University, Tuskegee University. **Selected Refereed Publications:** none

Effect of landscape position on crop yield when transitioning from conventional to conservation tillage systems. Many producers who are using conventional tillage systems mistakenly think that they must suffer several years of reduced crop yields prior to their soils responding positively to a reduced tillage system. The first phase of a large 20-acre long-term field experiment was completed to determine the impacts of transitioning from a conventional tillage to a conservation tillage system. This experiment was the first in the region to examine interactions among crop management systems, productivity, and landscape position using soil survey, topography, and electrical conductivity maps to define management zones. Results indicated that in every field management zone (including knolls, severely eroded side-slopes, and valleys) the use of conservation systems resulted in immediate increased crop productivity (14% on average for cotton), as compared to the conventional tillage systems. The results of this experiment indicate that producers who farm Coastal Plain soils can immediately begin to take advantage of increased yields when converting their row-crop production system from conventional tillage to conservation tillage. **ARS Locations and Cooperators:** Auburn, Watkinsville, Alabama Cooperative Extension Service, NRCS, Auburn University. **Selected Refereed Publications:** Balkcom et al 2005. Terra et al., 2004. Terra et al., 2005a. Terra et al., 2005b.

No-tillage allows more intensive and flexible dryland cropping systems and improves soil quality. Dryland cropping systems on the Central Great Plains are subject to frequent and cyclic drought spells. Even during periods of normal precipitation, available soil moisture is marginally adequate for most crop production that has wheat-fallow as the established crop rotation. A long-term cooperative research project has focused on investigating no-tillage as a way to conserve soil moisture and grow more intensive crop rotations, such as wheat-corn-fallow, wheat-corn-millet-fallow, or wheat-corn-sunflower-fallow. This research has established that no-tillage conserves more soil moisture and allows more intensive and flexible cropping choices. It also improves soil organic matter in the surface layer that helps enhance rainfall infiltration. These and similar research results from the ARS Central Great Plains Experiment Station, have convinced the farmers to convert more than half a million acres of wheat-fallow to more intensive cropping systems, and this conversion is still increasing. **ARS Locations and Cooperators:** Fort Collins and Colorado State University. **Selected Refereed Publications:** Campbell et al., 2005. Sherrod et al., 2005. Shaver et al., 2003. Sherrod et al., 2003. Shaver et al., 2002.

Conservation practices improve soil, air, & water quality and increase profits in perennial grass seed production systems. Due to a growing concern for environmental protection of air, soil, and water and a need to improve farm profits, ARS scientists recognized the need to research ways to improve grass seed production systems for the 660,000 acres produced in the Pacific Northwest. Several on-farm multi-year studies, some 10 years in duration, and at several locations, were established using large plots, and in some cases adjacent riparian buffers. Facilitation of research and technology transfer goals was enhanced by active participation of local stakeholders (farmers and environmental groups) and State and Federal scientists and extension representing multiple disciplines. These multi-factorial experiments demonstrated that perennial grass seed crops could be economically produced without burning post-harvest straw and by using no-till seeding in combination with straw chop after harvest. Compared to conventional tillage establishment with straw removed by baling, the ARS conservation system reduced soil erosion 40-77%, nitrate leaching 50%, establishment costs $27-162 per acre, can increase seed yields, allow earlier spring planting times, and increase recreation time for farmers. Growers are experimenting with how to best use these new practices on 15,000 acres in Oregon and Washington, and the USDA-NRCS has adopted no-till seeding and full straw management as practices to help grass seed farmers qualify for USDA Farm Bill conservation program payments for the first time. **ARS Locations and Cooperators:** Corvallis, Oregon State University, USDA-NRCS, and US-EPA. **Selected Refereed Publications:** Field et al., 2003. Wigington, Jr. et al., 2003. Butler et al., 2004. Gislum and Griffith et al., 2004. Steiner et al., 2006.

Reduced tillage in potato production systems. Reducing production costs through the use of conservation tillage and reduced inputs is a means of increasing the environmental and economic sustainability of Pacific Northwest potato production systems. Adopting conservation tillage to reduce erosion, increase N use efficiency, and build organic matter would improve soil and environmental quality under irrigated production systems. The major focus of this research is to evaluate the processes controlling soil biological activity and community structure of the soil micro-flora, understand the mechanisms controlling weed dynamics and evaluate carbon and nitrogen cycling, as well as, trace gas fluxes under reduced tillage in irrigated potato production systems. This study is in its third year under center pivot irrigation. A reduced tillage strategy was developed that uses equipment currently available to growers and has shown potato tuber yields under reduced tillage equaled that of conventional tuber yields. This strategy reduces the total number of passes across the field from nine to six, and soil disturbance operations from seven to four (including harvest), compared to those using conventional tillage. For sweet corn in rotation, field operations were reduced 50%. Preliminary findings suggest that growers adopting reduced tillage in potato production systems can reduce production costs through savings in fuel, labor, and equipment wear. **ARS Locations and Cooperators:** Prosser, Washington State University, Oregon State University, and AgriNorthwest Corporation. **Selected Refereed Publications:** none

Developing a strip tillage system for small seeded crops. The high prices of fuel and fertilizers have growers looking for new ways to maintain or improve sugarbeet productivity, while reducing operating costs. Strip tillage used to save fuel and reduce soil erosion, has not previously worked well for small-seeded crops like sugarbeets because of poor soil-to-seed contact. A special strip till implement was designed and built as part of a conservation tillage system that also includes modified weed and pest control, fertilization, irrigation management, and harvesting techniques. A four-year study was initiated in autumn 2003 to compare conventional grower practices with flat-planted, sprinkler-irrigated sugarbeets grown after spring grains. Substantial savings in fuel were obtained as tillage and fertilization are done in one equipment pass with the strip tiller, compared to up to seven passes under conventional tillage. In 2004, there were no significant differences in yields or sugar production between the two sets of treatments; however, in 2005 the strip tilled plots produced about 17% greater yields, primarily due to spring wind erosion protection provided by the standing straw stubble. In contrast, the conventionally tilled plots were severely damaged. Percentage beet sucrose was also higher in the strip tilled plots. After only two research seasons, one grower has purchased the specialized equipment and strip tilled more than 1,000 acres for the 2006 growing season. The local sugar company is recommending the system to its growers, and as much as 9,600 out of about 50,000 acres in production, based on this research. **ARS Locations and Cooperators:** Sidney, Montana State University, Sidney Sugars, and Schlagel Manufacturing. **Selected Refereed Publications:** none

Conservation tillage and cover crop benefits for cotton and soybeans. Significant interest was expressed by customers and stakeholders to find ways to reduce production inputs without major reductions to yield, and simultaneously minimize the environmental impact to the surrounding area. Systems studies were conducted to investigate the effects of reducing inputs using conservation management practices, and develop more efficient methods of applying agrochemicals in cotton production. The studies compared traditional tillage-intensive methods of cotton production to conservation methods using varying degrees of reduced tillage and incorporation of a cover crop. Significant yield increases were observed in cotton grown in the alternate-year rotation with corn, compared to the continuous cotton. Results indicate significant reduction in the tillage input can be achieved with minimal change in cotton yield. Moreover, no-till cotton production can be more profitable than conventional production methods. The change from conventional production to conservation tillage production practices requires varying degrees of equipment change. Therefore, the environmental and economic factors will need to be considered carefully on a case-by-case basis before making these changes. This study, conducted as part of the Mississippi Delta Management Systems Evaluation Area project evaluating sensor-controlled hooded sprayers, also resulted in 75% reduction in herbicide usage compared to typical chemical weed control methods in conservation tillage systems. **ARS Locations and Cooperators:** Stoneville, U.S. Geological Survey, Delta Research and Extension Center, MSU, Mississippi Department of Environmental Quality, Mississippi Soil and Water Conservation Commission, Mississippi Farm Bureau Federation. **Selected Refereed Publications:** Bryson et al., 2004. Hanks et al., 2004. Hanks et al., 2001. Bryson et al., 2001. Wesley et al., 2001.

Systems approach improves adoption of conservation tillage systems in the Southeastern U.S.A. Identifying multiple benefits of conservation tillage systems at the farm scale can help increase adoption. Researchers from ARS locations conducted multidiscipline on-farm research to improve conservation tillage systems for cotton. An approach was developed to ensure interaction among scientists and producers in identifying critical issues important to producers. Adding cover crops to the production systems increased yields and lowered insecticide use, resulting in overall more profitable cotton production, compared to conventional cotton without a cover crop. There was little difference in the effect of cover crop systems on soil microarthropod communities. Strip-tillage with in-row sub soiling increased cotton yield over strict no-till in these sandy coastal plain soils, and winter rye consistently produced great amounts of biomass and soil cover. However, N availability following rye was decreased, compared to some other cover crops, indicating that N applications need to be increased. Research results were provided to over 2,000 Southeast producers by establishing field demonstration plots and participating in field days. This is a maturing systems accomplishment with a few publications and additional outreach activities still in the works. **ARS Locations and Cooperators**: Watkinsville, Tifton, Dawson, Auburn University, NRCS, University of Georgia, US-EPA. **Selected Refereed Publications:** Schomberg et al., 2006. Schomberg et al., 2003. Tillman et al., 2004.

Increasing Adoption of Conservation Tillage Technology in the Tennessee Valley Region: Soil erosion and compaction, and weed pressure are management concerns to growers in the Tennessee Valley. Soil erosion from continuous cotton cropping and governmental regulations caused cotton producers in the Tennessee River Valley of northern Alabama to try no-tillage in the early 1990s, but yield reductions prevented widespread adoption of this system. Research developed a conservation cropping system for the Tennessee Valley region that included non-inversion fall tillage, and has been expanded to include improved nitrogen management and irrigation efficiency, and development of tillage systems to maximize water infiltration and reduce erosion. The research results were rapidly transferred via popular press articles to growers, consultants, extension agents, and NRCS staff, resulting in adoption rates of conservation tillage exceeding 70 to 80% in the largest cotton producing counties in the region (over 120,000 acres of conservation tillage cotton). When this research was started in the mid-1990s, only 30-40% of producers in this region were using conservation tillage technology. **ARS Locations and Cooperators**: Auburn, Auburn University, and USDA-NRCS. **Selected Refereed Publications:**

Conservation tillage systems for hot and dry climates. Excessive cultivation and high winds in the Rio Grande Valley of Texas have resulted in appalling rates of soil erosion and losses of soil organic matter, which declined from 4% at the time of settlement, to as low as 0.3% today. To counter these losses and improve soil productivity, a tillage system was developed that conserves soil and soil organic matter through reduced tillage and conservation residue management on cotton, corn, and sorghum fields. Sweet corn and broccoli also benefited from adoption of the conservation tillage practices. When adopted, these systems doubled organic matter in nine-years and wind erosion was prevented. Soils with 60% crop residue cover accumulated soil blown from nearby fields. Cotton and corn residue management was aided by the finding that plant polyphenols contribute to organic C retention when residues are managed correctly. Weed control through a modified ridge tillage system was critical. Soil nutrient distribution became stratified, enriching the surface 10 cm of soil with P, N and C. Coupling new soil management tools to new cropping strategies, such as including legumes in rotation, presented challenges regarding nodulation of the legume that continue to be investigated. Conventional, organic, and transitional growers are using these results, since they are scale-free and support sound soil management in many cropping systems. Farmers have readily adopted these practices because production costs are lower. The NRCS Energy Consumption Awareness Tool calculates, based on growing cotton, corn, and grain sorghum, fuel savings of $17.25 per acre compared to conventional practices. These integrated systems have been adopted on more than 350,000 acres in just the four-county lower Rio Grande Valley area of south Texas. **ARS Locations and Cooperators:** Weslaco, Texas A&M University extension. **Selected Refereed Publications:** Chaoui et al., 2003. Materon et al., 2001. Materon et al., 2003. Zibilske et al., 2003. Zibilske et al., 2005.

2. Rotation Crop Sequences. Rotation crops can provide a wide range of benefits. The interest in rotation crops is fueled by several factors: increasing input cost, environmental concerns, increased responsiveness to changing market conditions, pest control, and risk management. The research accomplishments demonstrate how the use of rotation crops can reduce the environmental impacts of agriculture such as lower use of toxic chemicals and runoff. They also show that the use of rotation crops leads to integrated systems that are more robust under a wide variety of physical and economic conditions. Furthermore, several studies show that the use of rotation crops can improve farm profitability and reduce economic risk.

Diversifying crop rotations and reducing tillage can reduce risk to Northern Corn Belt farmers. Despite national trends toward adoption of conservation tillage, farmers in the Northern Corn Belt continue to use intensive tillage. In addition, there has been a reduction in crop diversity in this area. Farmers need assurances that using new production practices will not put them at further risk of financial loss. The research showed that ridge tillage increased profitability, reduced fuel and labor use, and reduced economic risk, relative to conventional tillage for a corn and soybean rotation. The research also showed instead of continuous corn production, corn rotations including soybean, spring wheat, and alfalfa were valuable risk management tools when government payments and crop insurance are not available. However, when growers choose to use both government programs and crop insurance, the relative benefits of crop diversification in reducing risks are decreased. This new research is also beginning to show that no-till and many strip tillage systems increased profitability and reduced fuel use for a corn and soybean rotation, compared to moldboard plow and chisel plow tillage systems. The research is helping assure Northern Corn Belt farmers who want to adopt more sustainable production practices that reduced tillage and diverse crop rotations can reduce economic risks and complement other risk management tools including government programs and crop insurance. The research can also help policy makers find creative ways to design programs that provide economic incentives for producers to adopt conservation practices. **ARS Locations and Cooperators:** Morris, Brookings. **Selected Refereed Publications:** Archer, et al 2002.

Dynamic systems approach to rotation crop selection. Agricultural producers in the northern Great Plains face challenges when determining the best cropping sequence to maximize their production, have the greatest benefits for the environmental, and meet personal farming goals. A crop sequencing project was done that involved a crop-by-crop residue design, where 10 crops were planted on the residues from the same crops. This combination of 100 crop sequences allowed evaluation of the positive and negative effects of crop sequences in similar soil and water conditions. The project allowed evaluation of contrast effects for crop rotation (including annual forage and cover crops), residue removal, and tillage (minimum and no-till) on production, precipitation-use efficiency, plant diseases, and soil quality. The project was established in 1993 and just completed its twelfth year. The research was used to develop the *Dynamic Cropping Systems* concept. *Dynamic Cropping Systems* is a management philosophy emphasizing using adaptability and knowledge transfer to achieve a producer's production, economic, and resource conservation goals. *Dynamic Cropping Systems* has been transferred to end-users through peer-reviewed journal articles and a symposium involving Great Plains cropping systems researchers from Texas to Canada. An easy to use CD version of *The Crop Sequence Calculator* was developed that allows producers to evaluate the advantages and disadvantages of the different crop sequences based on information about production economics, soil water use, surface soil properties, plant diseases, weeds and insects. Over 12,000 copies of the CD have been distributed to producers, extension agents, consultants, and university educators, and been featured in popular press articles and as an exhibit in the congressional briefing. **ARS Locations and Cooperators:** Mandan. **Refereed Publications:** Krupinsky et al., 2006. Liebig et al., 2006. Merrill et al., 2004.

3. Cover Crops, Crop Residues, and Manure Use. Innovative cropping systems that make use of non-purchased inputs (e.g., manure) and integrate biological components (e.g., cover crops, residue management) may allow producers to reduce the cost of purchased inputs. Research activities are underway to investigate important components of such systems, and to develop and test integrated cropping systems that include these components.

Cover crop-based production system may be a potential alternative to methyl bromide. Agriculture in the southeastern U.S. has been negatively impacted by the North America Free Trade Agreement (NAFTA), which opened the borders and eliminated tariffs on free trade with Mexico. Also, the Montreal Protocol banned the manufacture, sale, and use of methyl bromide in the U.S., but extended its use in Mexico and other developing countries. These two policies have flooded U.S. markets with imported vegetables, leaving the U.S. growers less competitive. Research was conducted to evaluate the feasibility of using a biologically-based system for winter production of fresh-market tomatoes. The system consisted of a crop rotation in which nematode-resistant cover crops (cowpea, velvetbean, or sun hemp) were followed by a nematode and *Fusarium-Verticillium* resistant tomato cultivar. In selected years, tomatoes grown in the cover crop-based systems produced equivalent or higher yields, and had net returns equivalent to the conventional methyl bromide fumigation system. Additional research is needed to define the viability of this system across a wider range of nematode, disease, and soil conditions. These results show methyl bromide is not necessary under all conditions, and that use of a cover crop may be an economically viable alternative for growers of high-value crops in the southeastern U.S. In addition, the alternative system reduced soil erosion, improved soil fertility, and has great potential for protecting the environmentally fragile agro-ecosystem of the Everglades. **ARS Locations and Cooperators:** Beltsville, University of Florida. **Selected Refereed Publications:** Abdul-Baki et al., 2004a. Abdul-Baki et al., 2002. Wang et al., 2002. Abdul-Baki et al., 2004b. Roberts et al., 2005.

Utilizing fall-planted cover crops for weed suppression in potato production systems. Weeds in potato can reduce tuber yield up to 50%, reduce tuber size and specific gravity, reduce harvest efficiency, and harbor nematodes and pathogens. Greater than 90% of the potato acreage in the U.S. is treated with at least one herbicide to control weeds. It was demonstrated that autumn-planted cover crops of oat/vetch, mustard, and winter wheat can reduce the weed incidence in potato as well as reduce soil erosion, reclaim leachable nitrogen, increase water infiltration rates, and suppress nematode and potato pathogens - thereby lowering fumigant rates. Growers have rapidly adopted use of autumn-planted mustard cover crops on over 20,000 acres annually in Washington State. **ARS Locations & Cooperators**: Prosser. **Selected Refereed Publications**: Collins et al., 2005.

Cover crops enhance date production. Date production is localized in the Coachella Valley in southeastern California and generates about $38-million annually. Due to a number of stresses including high soil compaction, low fertility, and lack of organic matter in sandy soils, date yield and fruit quality have been declining. A two-step solution was developed consisting of deep slip plowing between the tree rows to break the hard pan and allow the movement of water and nutrients deeper into the soil profile, and a management system using a native Lana vetch to cover the soil surface from October to May. The cover crop suppressed weeds, improved soil fertility, recycled macro- and micro-nutrients, improved water percolation, shaded the soil surface, reduced evaporation, and lowered soil temperature in this excessively hot region. Within three years after implementing, tree growth tripled, yields increased by an average of 12-20%, and fruit quality was improved. At the same time, production costs were reduced by $100 per acre due to savings on cultivation, fertilizer, and irrigation. Approximately 45% of the date orchards in Coachella Valley are presently applying the cover cropping system. In addition, this technology has been extended to other crops resulting in an increase of cover cropping acreage from 500 to 25,000 acres in the Coachella Valley, including use on approximately 40% of the grape acreage. **ARS Locations & Cooperators**: Beltsville and USDA-NRCS. **Selected Refereed Publications:** Abdul-Baki et al., 2002.

Evaluation of novel cover crops. Many farmers rely on a few cover crop species, varieties, and mixtures; thus are particularly vulnerable to cover crop failure in case of disease or pest outbreak. Several rye breeding lines from the University of Florida were evaluated for use as winter cover crops, and novel cover crop mixtures of legumes, cereals, and mustards were used. This research identified several promising novel cover crop mixtures, and a rye breeding line that was well adapted to the Salinas Valley, California, vegetable production area. Collaboration with a local seed company resulted in the release of a new rye variety for commercial use. This research played an important role in the increased adoption of cover cropping by farms in the region. Farmers have used new rust resistant rye variety and novel cover crop mixtures on more than 2000 acres of land, a significant land area in this high-value fresh market vegetable production region. **ARS Locations & Cooperators**: Salinas, University of Florida, L.A. Hearne Company. **Selected Refereed Publications**: none.

Cover crop roller technology may be a key component of conservation systems. Cover crops have been shown to provide beneficial results for crop production and environmental protection. However, cover crops can interfere with cash crop establishment and growth. Roller crimper technology may provide a valuable alternative to chemicals for killing cover crops, with the added incentive of providing a flat, unidirectional mat of residue cover for planting into. A custom-designed roller effectively and economically killed cover crops in conservation tillage systems. In addition, alternate designs that reduce the vibration associated with rolling cover crops allow tractor drivers to traverse the field at typical speeds. One of the designs has resulted in a U.S. Patent. This information is being used by producers and manufacturers to create better implements that enhance the use of conservation systems for row-crop production. The technology is now being considered by other ARS researchers who use cover crops in their studies. **ARS Locations and Cooperators:** Auburn**,** Watkinsville**,** Alabama Cooperative Extension Service, NRCS State and National, Auburn University. **Selected Refereed Publications:** Ashford et al., 2003. Raper et al., 2005. Raper et al., 2004.

Discovering the molecular mechanisms that cover crops influence in production systems. Legume cover crops mulches were shown to influence many aspects of cropping systems including enhancing crop production and inhibiting weed and pest populations. A network of scientists from diverse disciplines was assembled to study process level interactions of cover crops within agro-ecosystems. Molecular approaches demonstrated that expression of select genes and proteins is enhanced during delayed crop senescence and increased disease tolerance in hairy vetch grown tomato plants. The team has the capacity to extend our understanding of mechanisms by which cover crops influence agro-ecosystems that could lead to more precise management practices for enhancing cover crop use. **ARS Locations & Cooperators**: Beltsville, Fargo, Ithaca, Cornell University, Boyce Thompson Institute, Purdue University, University of Maryland, Salisbury and College Park. **Selected Refereed Publications**: Kumar et al., 2004a. Kumar et al., 2004b. Kumar et al., 2005. Mills et al., 2002. Teasdale et al., 2004. Rice et al., 2005.

Residue management attachment developed for no-till drills. Conservation farming systems are problematic when excessive and poorly distributed surface residue causes poor no-till drill performance, uneven seedling emergence, slow plant growth, and depressed crop yields. To overcome this problem, a drill attachment was developed to manage crop residue next to the furrow openers of hoe-type no-till drills, improving seedling establishment by over 17% and crop yield by up to 12% in conservation farming systems. The patented residue management wheel is commercially viable because of its adaptability to a number of popular drill-opener geometries. Equipment manufacturers and researchers in Oregon, Washington, Canada, and Australia are experimenting with how to best use the residue management wheel on several thousand acres. In addition to improving system profitability, the ability to seed into high residue levels will eliminate the need for field burning, thus improving air- and soil-quality and reducing greenhouse gas emissions. **ARS Locations & Cooperators**: Pendleton and researchers in Canada and Australia. **Selected Refereed Publications:** Siemens et al., 2002. Siemens et al., 2004. Siemens and Wilkins, 2006. Wilkins et al., 2002.

4. Integrated Practices to Minimize Pest Impacts. Populations of agricultural pests are a part of the natural agricultural ecosystem. Pest control has often been viewed as an isolated production practice. However, more is being done to incorporate other production activities as factors that may moderate pest populations to reduce the amounts of pesticides to sustain agricultural productivity. In some cases, pesticide use may be eliminated.

Regional efforts to reduce weed pressures in the Pacific Northwest. A coordinated weed and integrated systems research has just been created to address weed management issues in Pacific Northwest cropping systems; to develop improved precision nitrogen placement methods that use information from crop yield monitors and grain protein sensors; and investigate the soil, landscape, and climate factors that influence crop nitrogen demand, nitrogen use, and nitrogen loss across dryland landscapes. Solving production problems involving highly competitive weeds in wheat production systems, as well as the impacts of agriculture on water quality in the Pacific Northwest region are critical issues that must be solved to maintain a viable economic agriculture base. This multidisciplinary integration and linkage addresses a broad range of agro-climatic conditions, extends resources by avoiding research duplication, accelerates the delivery of new developments, and broadens the geographical base of stakeholder support for conservation research in Pacific Northwest. **ARS Locations & Cooperators**: Pendleton and Pullman. **Selected Refereed Publications**: none

Small grain cover crops reduce the need for herbicide applications. Cover crops may be useful for weed control but more research is needed to discover their successful management and benefits. Research in the mid-west demonstrated that autumn-planted small grain cover crops reduced soil erosion, nitrate leaching, and suppressed weeds in whole-system experiments. A single herbicide application to winter rye at anthesis, compared to application at the 2nd node growth stage, lowered subsequent weed density in soybean by 81%. No-tillage soybean following a rye cover crop using mechanical control alone may be a viable management system for organic producers. These maturing research findings are helping USDA-NRCS and non-government organizations refine standards and educational programs to encourage the use of cover crops to reduce production costs, decrease nutrient and sediment contamination of surface waters, and still maintain productivity. **ARS Locations & Cooperators**: Ames, Iowa State University, USDA-NRCS. **Selected Refereed Publications**: Westgate et al., 2005. Singer and Kohler. 2005.

Cropping practices and rotations reduce the negative impact of weeds in potato production systems. Weeds of the Solanaceae family harbor nematodes and pathogens of potato resulting in increased nematode and disease incidence in potatoes. Soil fumigation is used to control corky ringspot disease (CRS) and root knot nematodes, costing $22-million annually in Washington State. Cropping practices have been developed that utilize weed-free alfalfa or spearmint rotations to eliminate CRS and reduce the need for fumigation. Likewise, scientists coupled root knot nematode resistant potato breeding lines with improved nightshade control practices that allows growers to grow a marketable potato crop in soils containing root knot nematodes. Research revealed a key in both these cropping systems was elimination of hairy nightshade and certain other weeds. Growers can utilize these findings to cleanse CRS from problem fields and reduce the need for soil fumigation to control nematodes. **ARS Locations & Cooperators**: Prosser. **Selected Refereed Publications**: Boydston et al., 2004. Hutchinson et al., 2005a. Hutchinson et al., 2005b.

Management strategies in rotation crops reduce populations of volunteer potato. Volunteer potatoes, prevalent in potato growing regions with mild winter temperatures, are considered a weed and are difficult to manage in crop rotations. Volunteer potatoes harbor pathogens, insects, and nematodes of potato, resulting in increased pesticide use totaling $6-million annually and management costs for rotation crops exceeding $5-million annually in Washington State. ARS Scientists have developed management practices for volunteer potato based on biology of the weed, cultivation and herbicide interactions, rotation crop competitiveness, biological control, and tillage level. Management options developed in sweet corn eliminate 99% of new tubers produced by volunteer potato. Management options including carrot, onion, and sweet corn prevent all yield and quality losses caused by volunteer potato. Growers can utilize these practices to improve yields, reduce losses from volunteer potato, and reduce disease, insect, and nematode problems and pesticide use in the potato crop. **ARS Locations & Cooperators**: Prosser. **Selected Refereed Publications**: Boydston, 2004. Williams, II et al., 2004. Boydston and Williams, II et al., 2005. Williams, II and Boydston, 2005. Williams, II and Boydston, 2006.

Integrated management strategies reduce jointed goatgrass in the Pacific Northwest. Jointed goatgrass is a winter annual grass weed introduced from Eurasia and is genetically similar to winter wheat. Infestations in winter wheat fields in the western United States costs growers more than $145-million annually. Normal production practices from area were compared to a range of integrated practices that included a one-time residue burn, crop rotation, use of competitive cultivars, varying seeding rates and dates, and large seed size. Even though jointed goatgrass is not entirely dependent on cold weather for reproduction and can produce viable seed from spring germinating plants, competition can be reduced in integrated management systems. At one study location, crop yield was increased 20% and crop quality increased 50% in the integrated system, compared to the growers' conventional system. Many of these integrated strategies have been adopted by winter wheat producers in the western United States. The alternative strategies reduced jointed goatgrass dockage in wheat that met the clean-grain standards desired by Gulf Coast and Pacific Rim countries. **ARS Locations & Cooperators**: Pullman and Washington State University. **Selected Refereed Publications**: Walenta et al., 2002. Young et al., 2003.

No-till spring cropping system decreases downey brome populations. The most prevalent wheat production system in the Pacific Northwest is the winter wheat-fallow system which encompasses almost 4.5 million acres. This system is characterized by winter annual grass weeds, soil borne diseases, poor soil quality, and is erosion-prone. For 12 years, a multi-disciplinary team of scientists and a group of interested producers conducted a long-term, field-scale integrated crop management research approach to develop conservation tillage spring cropping systems. No-till spring cereal rotations and reduced-tillage winter wheat fallow decreased downy brome populations more than 99%, compared to conventional wheat-fallow. In addition, conservation tillage wheat-fallow was profitable and reduced tillage operations more than 60%, compared to conventional wheat-fallow. A survey was conducted that documented for US-EPA that more than 60% of the spring cropping systems field day attendees conducted independent trials with one or more research technologies and that 50% of these trials resulted in permanent adoptions. This research has greatly redirected the focus of agronomic research in the Pacific Northwest and other national semi-arid wheat production regions. **ARS Locations & Cooperators**: Pullman, Washington State University, University of Idaho, Oregon State University, Washington Wheat Commission, USDA-NRCS, US-EPA. **Selected Refereed Publications**: Young and Thorne, 2004. Thorne et al., 2003. Forte´-Gardner et al., 2004.

Development of a biointegrated production system for strawberries eliminates the need for fumigation. Fumigation with methyl bromide for weed control is being phased out due to compliance with the Montreal Protocol. An ARS led multi-disciplinary team developed and tested variations of a biologically integrated production system for conventional strawberries to control weed in the absence of soil fumigation. The team integrated production system provided weed control and showed that mycorrhizal inoculants were not required. A CRADA was established and the research has since been adopted in one year on 400 acres of strawberries, representing approximately $8,800,000 in production costs. **ARS Locations & Cooperators**: Salinas, University of California, California Strawberry Commission. **Selected Refereed Publication**s: Bull and Vice, 1998.

Many approaches used together can increase New England agriculture profitability. There are approximately 23,000 diverse small farms in New England that require optimal combinations of rotation crops and conservation practices to achieve maximal individual profitability. The right combination of practices not only brings growers additional income, it can also be an effective way to suppress potato diseases, enhance soil nutrient content, and boost crop productivity—all while reducing the use of chemicals. Integrated soil, plant disease, crop productivity, and economic research have been used to develop potato crop rotations that increase profits. Incorporating canola into the rotation reduced *Rhizoctonia*, common scab, and powdery scab diseases by 20-50%, thereby increasing both potato yield and quality. Controlling the common weed hairy nightshade reduces a source of the fungus that causes Late Blight. Using ryegrass cover crops not only reduces soil erosion during the winter, but also helps to reduce *Rhizoctonia*. The introduction of raised planting beds seeded with green-sprouted potatoes consistently increases net income $40 per acre. **ARS Locations & Cooperators**: Orono, Maine Potato Board, National Potato Council, University of Maine. **Selected Refereed Publications**: Brewer and Larkin, 2005. Griffin and Porter, 2004. Halloran, 2006. Larkin, 2002. Larkin, 2003. Larkin and Honeycutt, 2006.

Development of a PCR protocol for rapid detection of *Cercospora beticola*. Cercospera Leaf Spot (CLS) is a major disease of sugarbeets (*Beta vulgaris*) around the world, and management options to minimize pesticide use require early and rapid detection. All current protocols to detect disease, while accurate, may take several days or weeks to complete, allowing for further spread of the disease if present in the interim. To address this problem, scientists have developed a PCR protocol for rapid detection of *Cercospera beticola,* the causal agent of CLS; which, unlike other molecular based protocols, can be done in less than one day and does not require isolation, subculture or purification of the genomic DNA of the target pathogen from symptomatic host plant tissues. PCR trials in the lab indicated that the method discriminated the target segment of the pathogen in the host tissue in one day, compared to several days using other methods. This newly developed PCR protocol is a powerful new tool for management of this pathogen in sugarbeets, and also enables a new avenue for extensive, timely screening and identification of secondary hosts such as weeds and other crops important in the control of the disease. This protocol also played a crucial role in recent identification of safflower, a major field crop in eastern MT and western ND, as a secondary host of *C. beticola*. The potential of the protocol was recognized by Sigma-Aldrich which is now marketing a kit based on published information on the Sidney protocol. The nucleotide sequence of *C. beticola* actin gene has been deposited with GenBank (Accession # AF443281). **ARS Locations & Cooperators**: Sidney, Fargo, Montana State University, and New Mexico State University. **Selected Refereed Publications**: Lartey, 2006.

Safflower is a secondary host of *Cercospora beticola*. Safflower (*Carthamus tinctorius* L.) is most often grown in dryland conditions, although it may also be produced in irrigated sugarbeet (*Beta vulgaris*) rotations and is often found in adjacent fields. Safflower had been previously reported to be susceptible to *Cercospora carthami,* which has never been reported to occur in the USA. Using the novel PCR-based rapid detection strategy and ELISA techniques, the researchers detected *C. beticola* in infected safflower plants and proved that safflower could be a secondary host. The infection of safflower (Family: Asteraceae) is the first known proof of family cross infection by a *Cercospora*, and also raises the possibility of cross infection of other crops by *Cercospora* species. This finding is highly significant, as it raises several questions with regard to rotation of sugar beet, safflower in particular, and viable crop rotations in general. There is also the possibility that *Cercospora* species that have been identified as pathogens of specific plant families may be isolates of a species that infect other families. Future research will verify this hypothesis. Growers, who are planning to rotate or are in the process of rotating safflower with sugar beet or plant the two crops adjacent to one another, are being made aware of the potential source of infection of *C. beticola* from either crop. **ARS Locations & Cooperators**: Sidney, Fargo, Montana State University, and New Mexico State University. **Selected Refereed Publications**: Lartey, et al., 2005.

Alley cropping of alfalfa reduces need for insecticides, thus increasing profitability potential. Alfalfa forage commands high prices and is in high demand. However, insect damage and the expense of frequent insecticide applications discourage production in many regions of the United States. The occurrence of insect-eating predatory bugs in alley cropping systems versus conventional alfalfa production systems were studied. Alfalfa alley cropped in 80-foot alleyways support insect populations that were twice as diverse and contained twice as many beneficial predatory insects than pest insects, compared to conventional monocropped alfalfa. These results imply that less insecticide may be needed to control alfalfa weevils in alley cropped alfalfa compared to conventional alfalfa, thus increasing production and reducing costly inputs. **ARS Locations & Cooperators**: Columbia and University of Missouri. **Selected Refereed Publications**: Stamps et al., 2002.

Conservation tillage with a rye cover crop reduces thrips populations in Southeast USA cotton. This research addressed issues associated with soil management, crop management, insect pests, and crop quality. ARS scientists in South Carolina found that early season populations of thrips, an early season insect pest of cotton, were lower in cotton grown with conservation tillage than in cotton grown with conventional tillage, especially when a rye cover crop was used. This may lead to improved integrated pest management recommendations for this cropping system. This research has contributed to the significant increase in acres where conservation tillage is being used for crop production in the southeast. Growers, consultants, extension agents, and NRCS personnel are the primary beneficiaries of this research. **ARS Locations & Cooperators**: Florence and Clemson University. **Selected Refereed Publications**: Bauer et al., 2004. Locke et al., 2005. Manley et al., 2003.

5. Overcoming Limited Water Availability. Supplemental irrigation is critical for some production systems, and can make the difference for being profitable. Profits can be increased through timely applications of the right amounts. Technologies are being developed to optimize water use efficiency and reduce the adverse impacts of irrigation on the environment. This research is also helping to reduce conflicts between rural and urban water users.

Optimization of crop performance through the proper water resource management. Increased pressure to maximize and stabilize crop yield has led to greater use of irrigation in the Mississippi Delta and notable depletion of the ground water. Research was conducted on crop water use and irrigation practices to increase the efficiency of irrigation water use in cotton cropping systems. This nascent research is aimed at improving management of water resources by providing suitable methods of irrigation scheduling, crop water detection, and tillage for use by local farmers. Information from weighing lysimeters installed in a cotton production field indicates that the traditional crop coefficients based on days-after-planting does not work well for humid regions. Development of more accurate crop coefficients for the region, together with suitable weather-based and soil-water balance models will improve irrigation scheduling effectiveness. Remote sensing systems, in-field sensors, and visual indicators that integrate the effects of soil type, weather, and evapotranspiration have been shown to be useful indicators of crop water stress and the need for irrigation. One simple scheduling tool (UGA EASY Pan - Evaporation-based Accumulator for Sprinkler-enhanced Yield) allows remote observation of evaporation that can be correlated with crop water use. The UGA EASY Pan was evaluated for use in Mississippi, with a potential 25% water savings. **ARS Locations & Cooperators:** Stoneville, Louisiana State University, Mississippi State University, Clemson University. **Selected Refereed Publications:** Pringle and Martin, 2003. Thomson and Brazil, 2002.

Feedback sensor systems for real time water management and self-propelled irrigation system decision support. Self-propelled center pivots and linear move irrigation systems are particularly amenable to site-specific, variable-rate applications. These systems also provide a platform on which to mount sensors for real-time monitoring of plant and soil conditions that can be supplemented with radio-linked, distributed, small micrometeorological and soil water sensing stations scattered across a field. A local, radio-linked ag-weather network is being developed so on-farm research results can be extended from one location to another. The local area weather network has now integrated with radio-linked, distributed field sensing stations to monitor real-time conditions of soil and plant conditions in MT and ND. A nascent decision support program with local and field sensing systems to control the variable rate irrigation is being developed. This research consolidates technology development and integration of self-propelled irrigation systems, variable-rate application controllers, distributed sensor networks, wireless radio telemetry, and decision support systems. **ARS Locations & Cooperators**: Sidney and Washington State University. **Selected Refereed Publications:** Leib et al., 2003. Jabro and Evans, 2006.

Decision support systems for irrigation scheduling in peanuts, corn, and cotton to improve profits and adoption. Persistent drought, urban expansion, and interstate litigation are collectively threatening irrigation water supplies in U.S. peanut producing regions. The National Peanut Research Laboratory has developed *Irrigator Pro* irrigation decision software and is involved in active technology transfer for commercial scheduling of irrigation in peanuts, corn, and cotton to assist producers in making improved decisions that will increase economic returns and conserve natural resources. *Irrigator Pro* for Peanuts has documented increases of 300 pounds per acre yield and 2% in *Sound Mature Kernels* which equates to an increased revenue of $60.25 per acre for growers using this systems. Based on these results, the Georgia Soil and Water Conservation Commission initiated an incentive program to encourage producers to adopt and follow the recommendations of *Irrigator Pro* for peanuts, corn, and cotton by providing payments to qualifying producers. In Georgia during crop year 2006, there were 2,700, 10,100, and 8,400 acres of corn, cotton, and peanuts included in the incentive program. In addition to the incentive program, adoption by producers and crop consultants is occurring due to the demonstrated benefits of *Irrigator Pro* for peanuts, corn, and cotton. The state supported incentives program based on Irrigator Pro results will be used in support of USDA Farm Bill Conservation Title Payments to interested producers. **ARS Locations & Cooperators**: Dawson. **Selected Refereed Publications**:

Davidson et al., 2002. Zhu et al., 2004. Sorenson et al., 2004. Lamb et al., 2005. Price et al., 2005.

Reduced supplemental irrigation in three Southeastern conservation tillage systems. Several factors have increased attention on agricultural water use including an increase in water withdrawals due to consecutive drought years, an increase in irrigated crop acreage, and interstate litigation regarding water rights and availability. Limits on the availability of water for crop irrigation in the Southeast have been imposed and the future expansion of irrigated acreage may be limited unless alternative methods of irrigation are adopted or current practices are made more efficient. Conservation tillage has the potential to reduce irrigation amounts and frequency of irrigations. ARS researchers have demonstrated that conservation tillage practices, such as strip-tillage into a rye or wheat cover crop, produced equivalent peanut and corn yields with 33% less supplemental irrigation in 3 of 4 years. Net return was highly year-dependent, but only conservation systems, either strip tillage or no-tillage, had positive net returns in each of four years in a corn-peanut-cotton rotation. Results from this on-going field study are being used to modify irrigation decision support systems. As a direct result of these studies, the Georgia Soil and Water Conservation Commission has recognized conservation tillage as an important aspect of water conservation plans that must now be in place for the permitting of new agricultural withdrawals. This research is helping to resolve some of the questions about conflict between rural and urban water users. **ARS Locations and Cooperators:** Dawson and Georgia Soil and Water Conservation Commission. **Selected Refereed Publications:** none

Nitrogen and irrigation best management practices for potatoes on coarse textured soils. Potato production in the Columbia Basin region of the Pacific Northwest is dependent on irrigation. Soils in this region are sandy and readily leach water and nutrients below the root-zone. Long-term research found that capacitance probes are effective tools for real-time, continuous monitoring of soil water content at various depths in the soil profile for potato production in sandy soils. Irrigation schedules that maintained optimal soil water within the root-zone were developed that also minimized leaching below the root-zone. A balance between pre-plant and in-season nitrogen management was identified for optimal production of high quality processing potatoes. Tuber yields as well as quality were not influenced by variable rates of pre-plant N or total N over the growing season, but since nitrate leaching is a concern in coarse textured soils, application of low rates of pre-plant N under irrigation was determined to minimize leaching losses without any negative impact on the tuber yield or quality. These results can be extrapolated to other potato production regions on coarse textured soils to maintain optimal production and further develop nitrogen and irrigation best management practices. **ARS Locations & Cooperators**: Prosser. **Selected Refereed Publications**: Alva et al., 2002. Alva et al., 2002. Alva et al., 2003. Redulla et al., 2002. Alva, 2004a. Alva, 2004b.

6. Precision Management Approaches. Farming operations are a complex mixture of activities with numerous interdependent decisions and tasks. Once, it was enough to make a decision and then hope for the best results. Today it is necessary to know which combinations of decisions are the most cost effective. This requires the application of one or more methods of analysis to make an evaluation, including at times simulation models as a part of the analysis process. Research accomplishments include new sources of spatial data for geographic information system mapping, new and improved methods of GIS map interpretation, and new uses for mapped spatial data for decision making.

Development of tools to rapidly assess crop status. Rapid measurement of crop status is critical for real-time management practices. However, traditional methods of acquiring information from the field are time and labor-intensive, and limited in coverage area. A range of tools are being developed for timely, accurate, and straightforward determination of crop and soil status for use by producers in crop management. Aerial videography and ground-based remote sensing systems have been developed that allow rapid, area-wide measurement of crop status. These are being used to develop indicators of tarnished plant bug infestation using several vegetation indices, and to indicate crop water status. Analytical tools developed by the team for rapid assessment of reflectance imagery allow researchers to utilize the entire spectral information from scanned crops, delineate physiological, morphological and edaphic indicators of crop status, and explore potential interactions contributing to the canopy reflectance. This research is a component accomplishment supporting systems research in cotton production. As these sampling methodologies mature and are adopted into production systems, it is anticipated that substantial benefits will be realized by producers through reductions in labor-intensive data collection procedures required for precision applications, and the generation of timely, accurate maps of crop and soil status for development of management plans based on potential crop performance and profitability. **ARS Locations & Cooperators:** Stoneville, Mississippi State University, and Texas A&M University. **Selected Refereed Publications:** Sassenrath et al., 2005a. Sassenrath et al., 2005b. Sassenrath et al., 2003. Tarpley et al., 2003. Thomson et al., 2002.

Sub-field management zones for improved crop nutrient utilization. Because many crop production fields are spatially variable for both soil nutrients and crop nutrient needs, conventional uniform fertilizer rates often exceed requirements for some field areas. In response to requests from farmers and consultants, we developed a decision aid to quickly process map information into management zones for variable-rate nutrient applications. The *Management Zone Analyst* (MZA) software uses quantitative, geo-referenced field information to mathematically divide a field into natural clusters or zones that are used to determine the optimal number of management zones for each field. Our approaches and software are widely used by researchers, commodity organization representatives, and agricultural consultants from at least 39 states and 35 foreign countries. Our prior work in the area of management zones was a key factor in the awarding of the project, *Implementation and Validation of Sensor-Based Site-Specific Crop Management* by the USDA Initiative for Future Agricultural and Food Systems. **ARS Locations & Cooperators:** Columbia, University of Missouri, ARS-CSWQRU, University of Illinois, Foundation for Agronomic Research. **Selected Refereed Publications:** Fraisse et al., 2001. Clay et al., 2002. Renschler et al., 2002. Fridgen et al., 2004. Kitchen et al., 2005.

Mapping soil compaction to identify field areas for precision tillage. Soil compaction plagues many producers in the Southeast U.S. Conservation tillage systems offer fewer opportunities for correcting soil compaction due to the reduced traffic allowed in fields. The time-consuming process of obtaining soil compaction measurements across a field with a soil cone penetrometer prompted the creation of a machine to measure soil compaction on a continuous basis. Coupling the *On-the-go Soil Strength Sensor* (OSSS) with site-specific GIS technology allows maps of soil compaction to be created. Because the cost of subsoiling can be expensive, soil compaction maps allow site-specific tillage to be applied at precise depths where needed, significantly reducing tillage power requirements and fuel costs. Improvements in technology necessary to map fields for soil compaction as well as the development of implements that adjust their tillage depth 'on-the-go' should contribute to a more energy efficient food production system. **ARS Locations & Cooperators:** Auburn, Oxford, Watkinsville, John Deere and Company, USDA-NRCS, and Auburn University. **Selected Refereed Publications:** Hall and Raper, 2005. Raper, 2005. Raper et al., 2005a. Raper et al., 2005b.

Soil maps guide soil sampling for microbial properties. Soil microorganisms are involved in carbon and nutrient cycles, soil aggregate formation and stabilization, and in the spread and prevention of crop diseases. Soil microbial properties are known to exhibit high spatial and temporal variability that greatly complicate their use in directing agricultural management. If soil microbial properties variability could be considered as a part of soil sampling schemes, it may possible to better understand the effect of management on soil microbial properties and how these influence crop production. It was shown that soil types delineated on soil maps can serve as initial demarcations for areas within a field that may have varying soil microbial properties, and it is important to consider sub-map unit variability when measuring soil microbial properties. This research is providing information to understand the impact of cropping systems on soil microbial properties. **ARS Locations & Cooperators:** Beltsville, Warren Wilson College, and University of Maryland. **Selected Refereed Publications:** Cavigelli et al., 2005.

Mapping soil electrical conductivity to understand sub-field grain production variability. Farmers and consultants want tools to help them understand yield variation across fields as a way to apply only needed fertilizers and other agricultural chemicals. Soil electrical conductivity (EC) has been shown related to grain production, but producers using commercially available EC sensors have raised questions about data collection and interpretation procedures. The value of different data collection procedures on accuracy have been compared using results from two types of commercial EC sensors. The research documented the relationships between EC and soil properties, both within specific soil associations and over multiple states. The correspondence between EC and grain yields has been related to both environmental and profitability issues, as well as used to facilitate the use of EC measurements to understand soil variations that impacts subsurface hydrology and optimum application rates of fertilizers and chemicals. Guidelines and information have been disseminated to farmers, consultants, and researchers across the U.S. and internationally. The two largest manufacturers of EC sensors for agriculture cite numerous research reports as reference material for their customers. **ARS Locations & Cooperators**: Columbia, Ft. Collins, University cooperators in Missouri, Illinois, Wisconsin, Michigan State, Iowa State, and South Dakota State, Veris Technologies, MFA, Inc., and numerous producers. **Selected Refereed Publications:** Kitchen et al., 2003. Sudduth et al., 2003. Officer et al., 2004. Jung et al., 2005. Kitchen et al., 2005. Sudduth et al., 2005.

Sensing technology to improve nitrogen application accuracy. Over-application of nitrogen fertilizer is a major problem in the Midwestern United States resulting in unnecessary production costs and contributing to water quality problems. Two site-specific management approaches based on crop canopy reflectance with ground-based or remote sensing and ultra-high resolution aerial images to predict nitrogen fertilizer needs across variable fields have been pursued. Optimal Applications rates would increase profit $15 per acre. Additional research using ground-based reflectance sensing systems is in process. **ARS Locations & Cooperators**: Columbia, Lincoln, Oklahoma State University, University of Missouri, NTech Industries, Holland Scientific, MFA, Inc., John Deere, and Missouri producers. **Selected Refereed Publications:** Scharf et al., 2002. Scharf et al., 2005.

Sensing technology for improved soil compaction measurements. Soil compaction is generally estimated by soil strength or mechanical resistance measurements and is difficult to efficiently assess within fields using current methods. One obstacle is simultaneously obtaining soil water content data to standardize strength measurements. A prototype soil cone penetrometer was developed that incorporated a near-infrared (NIR) reflectance sensor to measure soil water content. However, because penetrometers collect discrete point data, the spatial variability of compaction over short distances makes it difficult to accurately assess variability with a reasonable number of samples. To overcome this obstacle, a soil strength sensor was evaluated that that could simultaneously integrate data from five depths while moving across a field. The new sensor allows more thorough examinations of the relationship between crop yield and compaction and further site-specific compaction management. When commercialized, this 'on-the-go' sensor will also benefit practitioners on farms. A cooperative research and development agreement for additional development of the NIR sensing technology has been established. **ARS Locations & Cooperators**: Columbia, Ames, University of Illinois, University of Missouri, University of California, University of Nebraska, John Deere, Veris Technologies, and Missouri producers. **Selected Refereed Publications:** Chung et al., 2004. Hummel et al., 2004. Sudduth et al., 2004. Chung et al., 2005. Chung et al., 2006.

Sensing to improve nitrogen application accuracy. Research has shown that *Ion-Selective Field Effect Transistor* (ISFET) technology can rapidly analyze nitrate content in soil extracts and has demonstrated a method of rapidly extracting nitrate from a soil sample. Additionally, a usable combination of ion-selective membranes and extracting solution has been identified. Integrating these components into an automated soil sample collection and analysis system would provide a low cost 'on-the-go' rapid measurement technique that would automate the pre-side dress nitrate test. Approaches to assess varying nitrogen fertilizer needs, coupled with variable-rate fertilizer application, can potentially impact both the economics of corn production and the environment of the Midwest. **ARS Locations & Cooperators**: Columbia, University of Illinois, and Iowa State University. **Selected Refereed Publications:** Price et al., 2003. Kim et al., 2006. In press

Understanding within-field grain yield variability. Fundamental to precision agriculture management is accurate measurement of spatial yield variability and effective methods to relate that yield variability to variations in other site properties. Several approaches were developed to combine yield monitor data with inherent errors with techniques to screen and filter these data. Filtered yield monitor data have been related to site properties using path analysis, nonparametric statistics, and artificial neural networks that resulted in yield estimation models of variable accuracy from year to year. Application of *CERES-Maize* and *CROPGRO-soybean* models to estimate within-field yield variation on claypan soils identified needed improvements. Analysis of yield data collected on 12,000 acres over three years showed corn, soybean, and wheat yield variability was generally severe, widespread, and persistent. The greatest impact to date is the widespread use of the publicly available software that implements yield data filtering techniques. The software has been downloaded 500 times and numerous responses from users have commented about the usefulness of this product. **Locations & Cooperators**: Columbia, Florence, Mapshots, Inc., University Cooperators in Missouri, Illinois, Wisconsin, Michigan State, Iowa State, and South Dakota State, and several Missouri producers. **Selected Refereed Publications:** Chung et al., 2002. Drummond et al., 2003. Wang et al., 2003. Hong et al., 2004. Chung et al., 2005. Sadler et al., 2005.

Experimental designs for large commercial field precision applications. During a production season, many recommendations are necessary for producing the crop and impacts of these decisions need to be assessed to determine the best configurations of precision applications. A topologically based general linear mixed model approach was developed for the analysis of site-specific and traditional management practice effects on commercial farms. The geometries of farm equipment that are smaller than the largest machine create smaller experimental units nested within the larger ones. Geographic Information System (GIS) processing and a general linear, mixed-model approach, provides test statistics based on topological relationships among agricultural topography features. The analysis results provide feedback information to producers and consultants for future production seasons. The utility of the process has been demonstrated by completing the analysis of several commercial-field, site-specific experiments, which previously were not able to be analyzed by traditional statistical methods. A recent workshop was held to communicate selected results from these analyses to other investigators within the Mid-South Cotton Belt. As the analysis method is adopted by other investigators, better research of commercial field experiments will result, ultimately benefiting producers and researchers across several states. **ARS Locations & Cooperators**: Mississippi State, Stoneville, Mississippi State University, and Milliken and Associates. **Selected Refereed Publications**: Willers et al., 2004.

Development of Site-Specific N Indices for Precision N Management. Uniform N management is practiced throughout the Pacific Northwest Dryland Cropping region and much of the world resulting in large inefficiencies of N fertilizer use. Lack of decision support tools for site-specific N management has led to little adoption of available precision agricultural technologies. N Indices were used to diagnose the N use and agronomic performance of wheat across heterogeneous field conditions. These indices are based on field-scale information that can be collected by farmers with currently available technologies: wheat yield, protein and applied N fertilizer. These variables were used to quantify N use efficiency and classify wheat performance into 5 distinct classes. The classes range from N that was managed efficiently (Class 1) to N management that resulted in substantial losses to the environment (Class 5). The classification system was used to spatially map the performance of N management practices across agricultural fields. The N indices and classification system will be useful to farmers for evaluation and diagnoses of practice performance and for formulating more efficient N management practices. Currently, the N indices are being field tested to evaluate their effectiveness as a precision N management decision support tool. If successful, the estimated reduction in fertilizer N input for the region is 20 to 50%. **ARS Locations & Cooperators**: Pullman, Washington State, University, McGregors Farm Supply, Wilber-Ellis, Monsanto, John Deere, Case New Holland. **Selected Refereed Publications:** Huggins and Pan. 2003.

7. Integrating crops and livestock for best benefits. Many livestock producers operate on relatively narrow profit margins, making production efficiency particularly important. Although the potential for using diversification to reduce risk, reduce production costs, and increase profits is well understood by producers, most focus their efforts and specialize on either crop or animal production because integrated farming requires a wider knowledge base. A number of projects are working to provide the research-based information that producers need to efficiently manage integrated crop-livestock operations for reduced production costs and increased profits.

Integrated crop–livestock production systems for the southeastern U.S. Multiple ARS locations and university colleagues have worked together to develop a conservation tillage system for incorporating cotton-peanut production with winter-annual grazing. In research in the Southern Piedmont, grazing cover crops did not alter grain production but did increase system productivity due to animal gains. Preserving organic matter at the soil surface was important to mitigate potential compaction from animal traffic. In the Coastal Plain, profit was 2-3 times greater when cotton or peanut was grown following 80 days of stocker grazing on oat or annual ryegrass cover crops, than in conventional cotton or peanut systems. Profits were maximized on these soils by using some type of non-inversion deep tillage to alleviate compaction. **ARS Locations & Cooperators**: Auburn and Watkinsville, Auburn University, USDA-NRCS, and Alabama Cooperative Extension Service. **Selected Refereed Publications:** Siri-Prieto et al., 2006. In press.

Tillage requirements for winter-annual grazing rotations. Integrating livestock with cotton-peanut rotations may offer profitable alternatives for producers, but could result in excessive soil compaction that severely limit yields. A three-year field study developed a conservation tillage system for integrating cotton-peanut production with winter-annual grazing to maintain or improve soil quality and increase profitability. Net returns from winter-annual grazing were $64 to $83 per acre per year. Grazing increased soil compaction to the 4-in depth, but using conventional surface tillage or deep tillage reduced compaction and increased soil water removal by cotton and peanut, compared to strict no-tillage. Strict no-tillage resulted in the lowest yields (23% and 39% less than the mean for cotton and peanut, respectively) and non-inversion deep tillage was required to maximize yields with no-surface-tillage. The results of this work indicate that producers in the region can maximize profits by integrating winter-annual grazing with cotton and peanut using non-inversion deep tillage in conservation tillage systems. This system allows producers to raise revenue during winter months without sacrificing cotton and peanut yields. **ARS Locations and Cooperators:** Auburn, Watkinsville, Auburn University, Alabama Agricultural Experiment Station, NRCS. **Selected Refereed Publications:** none.

Modified hay production system improves ruminant feed intake. A simple modification to alfalfa hay harvest timing improved efficiency and increased economic viability through optimizing herbage soluble carbohydrates. Due to the diurnal fluctuation in photosynthesis, hay cut in the afternoon had the greatest sugar accumulation for alfalfa. Cattle, sheep, and goats preferred hay cut in the afternoon over the corresponding morning hay when offered a choice, and measures of forage quality were also greater for hay cut in the afternoon. Along with the preference, there was an increased daily intake of the afternoon harvested forage by goats and cattle; goats digested the afternoon forage to a greater extent than cattle. Similar results were not found for switchgrass in the southeast, probably due the different kind of crop and climate. Due to the simplicity of the technology, measurable increases in forage quality, and labor advantages from later-in-the-day haying operations, adoption has been extensive with over 80% of alfalfa growers surveyed responding that they were adopting the technology. Adoption is proceeding especially rapidly in western USA haymaking regions due to information disseminated by extension, grower organizations, and popular press articles. **ARS Locations & Cooperators**: Watkinsville, Raleigh, and Kimberly, University of Idaho, and Montana State University. **Selected Refereed Publications:** Burns et al., 2005. Fisher et al., 2002. Fisher et al., 2005.

Improved pasture utilization increases dairy cow feed efficiency. It has been estimated that managed intensive rotational grazing is practiced on 10 to 25% of dairy farms in the Midwest and Northeast. Inadequate intake of dry matter is a primary factor limiting milk production of such grazing-based dairy systems. Since grazing cows are dependent upon pasture for the majority of their feed requirements, optimum utilization of grasses at the appropriate stage of maturity is essential to maximizing intake. Preliminary research indicates that pasture grasses differ significantly in the distribution and quality of herbage from the top to the bottom of the canopy. For example, the upper third of a meadow fescue canopy is 300% more dense during the summer than orchard grass, and is 5% more digestible. Improved intake of higher quality herbage can improve the profitability and sustainability of grazing-based dairy systems by reducing the need for expensive grain supplements. **ARS Locations & Cooperators**: Madison and University Park. **Selected Refereed Publications:** none.

Tannins may increase dairy profits and enhance environmental quality. Production and feeding of tannin-containing forages on dairy farms could increase productivity and profitability while reducing environmental impacts. When birdsfoot trefoil with condensed tannin was fed in place of tannin-free alfalfa, dairy cattle produced 15% more milk and excreted 20% less urinary nitrogen – a form of nitrogen readily lost to the atmosphere. Models predict an increase in net returns of 7 to 12% and nitrogen loss reductions of 6 to 25%. In this initial analysis, tannins reduced the need for protein supplements by up to 60%, and increased the value of alfalfa silage by $23 and alfalfa hay by $11 per ton of dry matter. The potential worth to the dairy industry is $300 million per year. Ongoing feeding, field, and laboratory trials, along with computer simulations will identify optimal forage tannin levels and management practices for enhancing protein utilization and nitrogen cycling on dairy farms. **ARS Locations & Cooperators***:* Madison, University Park, Beaver, and university partners in Michigan and Utah. **Selected Refereed Publications:** Hymes-Fecht et al., 2004. Misselbrook et al., 2005.

Integrating annual forages into a Great Plains beef production system. Fed forage to livestock over winter is the single largest cost for producers in the northern Great Plains. Research has evaluated the potential of integrating swathed annual forages into a beef production system to reduce winter feeding costs. Costs were lowered by $0.24 per animal per day compared to a dry-lot, without adverse effects on middle-aged beef cow production. About half of the nitrogen used for protein production was derived from sources other than commercial fertilizer. The trends in the fourth year of the project suggested that livestock may enhance forage and grain production in the crops fields. This information may lead to lower-cost integrated crop-livestock systems. ARS **Locations & Cooperators**: Mandan. Liebig et al., 2006. **Selected Refereed Publications:** Tanaka, et al., 2005. Liebig et al., 2006.

Dairy herd management enhances nutrient cycling. Optimal nutrient use on dairy farms depends on what is fed to cows, herd management, and the balance between livestock numbers and land area available for feed production and manure application. Research has discovered critical, previously unknown relationships between dairy herd size, cropland area, and a farm's ability to grow feed and recycle manure nutrients through crops, and between farm size, livestock housing, herd management, and the amounts of manure collected and spread on cropland. A six-year field trial discovered that corralling livestock in fields between cropping periods captures and recycles more manure nutrients, which increases yields substantially, often for 2-3 years, and requires less labor than conventional confinement systems whereby manure is hauled, and most urine N is lost from barns. Corralling dairy cows on cropland is becoming increasingly attractive to farmers during the current era of escalating energy and fertilizer N costs. Based on these findings, regulatory agencies are considering use of animal:cropland ratios as indicators of whole-farm environmental performance, and as an additional factor to include in Comprehensive Nutrient Management Planning. The discovery that herd management on small farms leads to less manure collected than on large farms is refocusing policy towards special assistance to small farms in managing manure in barnyards and other outside areas where cattle congregate and manure goes uncollected.

ARS Locations & Cooperators: Madison, University of Wisconsin, Utah State University, and the Food Alliance. **Selected Refereed Publications:** Powell et al 2005. Saam et al 2005.

On-farm research improves nutrient management on dairy farms. Understanding the challenges livestock producers face in nutrient management is critical to focus research, extension, and policy on information and technologies to create opportunities that enhance farm profits and the environment. On-farm research aimed at improving the understanding of how farmers manage nutrients in realistic settings showed that most Wisconsin producers feed excessive amounts of P to lactating dairy cows, which increased dramatically the cropland needed for recycling manure and also affected greatly the duration before all cropland attained excessive levels of soil test P. The on-farm research questionnaires and other instruments developed in this study have been adapted for use in Iowa, New York, Ohio, Pennsylvania, Wisconsin, and Australia, and many of the on-farm research findings have been incorporated into nationally-distributed outreach materials. **ARS Locations & Cooperators**: Madison and University of Wisconsin. **Selected Refereed Publications:** Powell et al 2002. Powell et al 2005.

Refined dairy diets enhance profits and the environment. The sustainability of U.S. animal agriculture increasingly depends both on profitability and compliance with manure management regulations. Research has shown important relationships between dairy feeding practices, manure nutrient excretions, and the impact of these factors on profitability and environmental outcomes. The prevailing industry practice of feeding mineral supplements to lactating dairy cows increases total-phosphorus, water-soluble-P, and heavy metal concentrations in manure beyond what can be effectively recycled on cropland after manure application. These results have been incorporated into national outreach materials to change producer practices, and recent surveys of nutritionists and feed companies across Wisconsin show significant reductions in dietary P levels. The saving to U.S. dairy farmers is $30-35 million annually, and has the potential of an additional savings of $65-70 million. Mitigating environmental risks associated with reduced N and P loss from dairy farms due to reduced dietary N and P levels are “win-win” situations that will continue to enhance the profitability and environmental impacts of dairy farming in the US. **ARS Locations & Cooperators**: Madison and University Park. **Selected Refereed Publications:** Ebeling et al., 2002. Li et al., 2005. Misselbrook et al., 2005. Powell et al., 2006.

Problem Area B. Systems, Strategies, and Tools to Reduce Agricultural Risks.

The technology developed to address this goal include entire system analyses and the development of decision aids based on research results to guide a producer to an integrated decision. Simulation models of plant growth processes are also included to help predict likely responses if management changes are made by producers. Large scale techniques such as remote sensing and GIS provide field level information on crop status, give access to historical information that can be used to evaluate land use practices, and determine the best approaches to meet the specific needs of producers.

1. Alternative Risk-Aversion Production Systems. Research is being done to demonstrate certain production systems are better than others in reducing the chances of financial risk to producers.

Reducing tillage and diversifying crop rotations can reduce risk to Northern Corn Belt farmers. Despite national trends toward adoption of conservation tillage, farmers in the Northern Corn Belt continue to use intensive tillage. In addition, there has been a reduction in crop diversity in this area. Farmers need assurances that using new production practices will not put them at risk of financial loss. ARS has addressed the problem of reducing barriers to the adoption of more sustainable cropping systems using long-term studies to evaluate the effects of cropping systems on economic risk. The research showed that ridge tillage increased profitability, reduced fuel and labor use, and reduced economic risk relative to conventional tillage for a corn and soybean rotation. The research also showed corn rotations including soybean, spring wheat, and alfalfa instead of continuous corn production were valuable risk management tools when government payments and crop insurance are not available. However, when growers choose to use both government programs and crop insurance, the relative benefits of crop diversification in reducing risks are decreased. Recent research results showed that no-till and many strip tillage systems increased profitability and reduced fuel use compared to moldboard plow and chisel plow tillage systems for a corn and soybean rotation. The research is helping assure Northern Corn Belt farmers who want to adopt more sustainable production practices that reduce tillage and diverse crop rotations can reduce economic risks and complement other risk management tools including government programs and crop insurance. The research can also help policy makers find creative ways to design programs that provide economic incentives for producers to adopt conservation practices. **ARS Locations and Cooperators:** Morris, Brookings. **Selected Refereed Publications:** Archer et al., 2002.

Designing low-risk dryland cropping systems for the Northern Great Plains. Most dryland small grain enterprises in the Northern Great Plains are not economical without Federal transfer payments. A major agronomic concern is the limited diversity of crops in this semi-arid region that is subject to frequent drought. To replace spring grain-fallow systems, a team is developing intensive, no-till systems that increase crop diversity using new rotational sequences, reduce operation costs, and minimize agrochemical usage. Research is also determining short-term means for controlling weeds at the onset of intensive low-till or no-till farming efforts. The agroecological approach is showing that manipulation of planting times, straw height, herbicide programs and crop selection from year to year can substantially reduce pesticide use and conserve moisture, while also increasing carbon sequestration and reducing fuel consumption by growers. Two large-scale, long-term, multidisciplinary studies were begun in 2004. This research is directed toward understanding the complexity of these systems to quantify the economic and environmental benefits of these strategies that reduce risk. **ARS Locations and Cooperators:** Sidney, Roosevelt and Sheridan County Conservation Districts, USDA, CSREES, Montana State University, Roosevelt County Conservation District, Sheridan County Conservation District, and Mosaic Company. **Selected Refereed Publications:** Caesar-TonThat et al., 2001. Sainju et al., 2005. Goosey et al., 2005. Sainju et al., 2006a.

Sainju et al., 2006b.

Holistic approach to farm planning and conservation programs improves profitability and enhances natural resources conservation. There is need to find ways to increase farm environmental benefits while enhancing economic viability. This is particularly true in the Drift Prairie Region of the U.S. where extreme weather events caused persistent wet conditions and flooding and have exacerbated already tense relationships between environmental and agricultural interests. A five-year demonstration project was initiated to demonstrate the benefits of agricultural-environmental planning and cooperation. Each of four demonstration farms worked under a whole-farm plan developed by the producer and a six-member *Resource Analysis Team* comprised of agriculture and conservation professionals. As a part of this project, ARS conducted research on the economic performance of the demonstration farms in comparison to other farms in the region. Research results showed that farm debt declined significantly for three of the four farms, and all four farms had less indebtedness than regional averages. Conservation was a dramatically larger share of total government and conservation payments than regional averages, and these payments went directly toward purchasing residue conserving equipment resulting in potentially long-lasting shifts in production practices. Other parts of the project showed wildlife, water quality, and wetland carbon storage benefits and reductions in erosion. The research generated support among the producer-participants and involved many government and non-governmental groups at the Federal, State, and local levels, which will help promote conservation activities in the region. This project also provides a template for policy makers to use in designing future conservation programs for the region. **ARS Locations and Cooperators:** Morris and North Dakota Natural Resources Trust. **Selected Refereed Publications:** Clancy et al., 2006.

2. Models to Predict At-Risk Conditions and Best Responses to Management.

Specific decision support tools are being developed to help producers identify the best ways to produce their products with the least amount of economic risk.

Crop damage assessment tool for field-scale decisions. Crop damage assessment tools are needed to show producers which portions of their fields consistently produce non-profitable yields and to provide the Risk Management Agency (RMA) with ways to assess field-scale crop damage amounts. ARS Scientists in Iowa developed a tool based on the integration of field-scale geographical information system layers of soil types, topography, harvested yield, and remote sensing images. The researchers found that the remotely sensed data provided a measure of crop biomass needed to estimate potential crop yield. This tool is being incorporated into a process for producers to use as part of the field-scale crop damage assessment for RMA. **ARS Locations & Cooperators:** Ames. **Selected Refereed Publications:** Pinter et al., 2003. Hatfield et al., 2005

Research results used to identify profitable combinations of potato cropping practices for the Northeastern U.S. ARS researchers have integrated soil, plant disease, crop productivity, and economic research to develop the *Potato Systems Planner* decision-support software. The software weaves together eight years of research covering

14 cropping systems findings on yield, quality, profitability, grower risk, nutrient cycling, soil-born diseases, and soil microorganisms. Also, an *Economics Calculator* based on the same input as required for loan applications by the USDA Farm Service Agency, helps growers estimate profitability of each cropping system. Over 750 copies of the *Potato Systems Planner* have been distributed to growers and scientists from 21 states, seven Canadian provinces, and eight countries since 2005. **ARS Locations and Cooperators:** Orono, Maine Potato Board National Potato Council, University of Maine. **Selected Refereed Publications:** Franzluebbers et al., 2001. Larkin et al., 2003. Griffin et al., 2004. Halloran et al., 2005. Olanya et al., 2005.

Crop simulation for decision making in Pacific Northwest potato-based cropping systems. Tools to improve nitrogen management for potatoes in the Pacific Northwest are desirable in view of the concern on non-point source pollution of nitrate into groundwater in the Columbia Basin production region which is characterized by sandy soils and possible N inputs in excess of crop N requirement. The *CSPotato* model was integrated into the multi-year, multi-crop *CropSyst* simulation model to improve assessments of nitrogen fate under different fertilizer and irrigation regimes in potato systems. When the crop in rotation is potato, the potato model simulates potato growth and development and plant carbon and N balances. Validated model predictions have shown that 240 to 400 lbs. per acre of N was unaccounted and therefore could be considered as subject to leaching. The model will be made available for general use on Website.**ARS Locations & Cooperators:** Prosser, Beltsville, Washington State University. **Selected Refereed Publications:** Alva et al., 2003. Delgado et al., 2005. Alva et al., 2005.

On-farm research results in simple spreadsheet planning tools. Central Great Plains farmers and ranchers must manage for regular and cyclic drought, lower commodity prices, increased input costs. These factors coupled with government programs and crop insurance options make optimal decision making difficult. A program of on-farm research for testing *GPFARM* and related technologies was initiated with over 100 visits made by cooperators to collect whole farm information. This effort used in the development of the new *iFARM* decision support tool to help producers find the optimal balance between crops, insurance type and level of coverage, inputs, and lease options. The spreadsheets have been well received and the Colorado Association of Wheat Growers has made the spreadsheets available on their Website. **ARS Locations & Cooperators**: Fort Collins, Decision Commerce Group, Farm Credit of Southern Colorado, Colorado State University, and USDA-NRCS. **Selected Refereed Publications:** Ascough II, et al., 2002. McMaster et al., 2002.

The economics of crop rotation sequences and technology transfer to producers. Adequate rotation time between peanut crops is essential for maximizing peanut yield. Maximizing yield output is not the same as maximizing economic returns, and decisions on the best crop rotation system must consider the profitability of the system as a whole. The *WholeFarm* farm planning system was developed to assist growers in developing formal whole farm plans and has been distributed to producers in over 30 states. The Cross-Commodity Breakeven Price Matrix (CCBPM) is a recent addition to *WholeFarm* and will calculate the required price changes in crop grown in rotation with peanuts that would justify shortening or lengthening the rotation time. The CCBPM provides producers valuable information necessary to make farm planning decisions that incorporate scientific data with farm specific data. This optimization system has been used as an agricultural prediction component for a project supported by NASA determining the effects of long-term global change. **ARS Locations & Cooperators:** Dawson and Watkinsville. **Selected Refereed Publications:** Lamb et al., 2005. Sternitzke et al., 2000. Butts et al., 2004.

Producers can evaluate the 100 different crop sequences for the Northern Great Plains. Northern Great Plains producers need a simple way to evaluate the strengths and weaknesses of various cropping sequences. Scientists at the Northern Great Plains Research Laboratory in Mandan, North Dakota, developed the easy-to-use *Crop Sequence Calculator*. The *Crop Sequence Calculator* contains information on production economics, soil water use, surface soil properties, plant diseases, weeds and insects. Information for the calculator was gathered from crop sequencing experiments conducted at the Mandan location. Over 12,000 copies of the CD have been distributed to producers, extension agents, consultants and university educators. **ARS Locations & Cooperators:** Mandan. **Selected Refereed Publications:** none

Decision aids provide guidance to improve production efficiency, reducing input costs, and increase profitability. Producers face many management decisions that impact profitability and potential environmental impacts within a season. The *Nitrogen Decision Aid* provides producers information quickly and in a user-friendly format that enables them to make nitrogen use decisions efficiently. The *Nitrogen Decision Aid* utilizes weather, soil, and management data to estimate nitrogen side-dress needs and has been downloaded over 1400 times since its release in 2000. *WeedCast* utilizes weather, soil, and management information to estimate crop emergence time and weed growth estimates for 18 species, thus improving weed control by optimizing the timing of weed control measures. *WheatScout* builds upon the *WeedCast* model and combines information on wheat growth and herbicide application windows to assist producers in selecting herbicides and estimating optimal application timing and rate. *SeedChaser* allows farmers to evaluate the impact of tillage on resulting weed seed bank distribution and surface applied chemical incorporation following tillage. In addition, the *WEEDTURF* turf grass weed management model has been developed. **ARS Locations & Cooperators:** Morris, Fort Collins, Universidad Nacional de Rosario, University of Western Australia, and Growth Stage Consulting, Inc. **Selected Refereed Publications:** Ekeleme et al., 2005. Ekeleme et al., 2004. Masin et al., 2005.

Interactive decision aid developed to estimate stem rust disease development. Stem rust is the most important and damaging disease of grasses grown for seed in the Pacific Northwest. Over 400,000 pounds of fungicide are applied annually at an estimated cost of $10-million. The disease can be managed with fungicides that are typically applied on a 14-day schedule which result in more applications than required in most years. In addition, the effectiveness of fungicide sprays for rust control depends on knowing when to start spraying. An interactive decision aid to estimate stem rust disease development has been developed that collects real-time weather data from numerous grass seed fields and estimates the potential for stem rust development. Users can choose a location, enter their observed initial disease levels, and get an estimate of disease development in the presence and absence of fungicides for any date. The Web-based model allows managers to assess the timing and benefits of fungicide application and potentially to reduce costs. **ARS Locations & Cooperators:** Corvallis, Western Farm Service, and Oregon State University Plant Protection Center. **Selected Refereed Publications:** Pfender et al., 2003. Pfender et al., 2004a. Pfender et al., 2004b. Pfender et al., 2006.

How and why weeds differ between fields and among years. Geographic information system technology can be used to monitor changes in weed distribution patterns over space and time so the seriousness of weed problems can be determined and to identify linkages between specific agronomic practices and weed infestations. ARS Scientists developed procedures to georeference ten years of crop production and weed incidence data from a proprietary non-spatial database, and then created a georeferenced database to study changes in weed distribution and severity. Application of this technology led to identification of the five most aggressive weed species in established perennial grass seed stands, quantification of their aggressivity, and recognition that increased time out of grass seed production decreased the severity of four weed species and increased the severity of ten others. Quantifying changes over time in severity of major weeds has provided the grass seed industry with information critical for focusing future weed control research efforts, and for informing regulatory agencies in their decision making regarding herbicide registration requests. **ARS Locations & Cooperators:** Corvallis and Oregon Seed Services, Oregon State University. **Selected Refereed Publications:** none.

GLYCIM model increases irrigation efficiency for Mississippi Delta soybean growers. Soybean is an important crop in the Southeastern United States where irrigation is becoming more widespread. While there are guidelines for irrigation, a simulation model can allow growers to rapidly evaluate numerous options for estimating the effects of irrigation timing and amount on projected yield and harvest date where experiments have not been conducted. The GLYCIM soybean simulation model was tested with 12 growers over an eight-year period (1991 to 1999) in the Mississippi Delta region and two years in the Florida PanHandle (2004-2005) for making pre-season decisions on variety and row spacing selection, planting date, and in-season decisions for irrigation and harvest timing. Growers using the model attributed increases in yield up to 29% and irrigation use efficiency up to 400%. Based on the GLYCIM results, growers also decided to purchase additional irrigation equipment after seeing the yield increases due to irrigation predicted by GLYCIM actually occurred. This research has benefited both soybean farmers and scientists interested in quantifying environmental effects on soybean growth and development. **ARS Locations & Cooperators:** Beltsville, Mississippi State University, University of Maryland, Florida A&M University. **Selected Refereed Publications:** Ali et al., 2004. Koti et al., 2004. Reddy et al., 2002. Taylor et al., 2004.

The latest scientific knowledge and technology incorporated into GOSSYM and GLYCIM. Many crop simulation models use empirical relationships that are not appropriate for estimating plant response to global climate change, are inaccurate for simulating plant response to environmental stresses, or require re-parameterization for different locations. Using technology to measure plant physiological processes, plant responses to environmental conditions at great detail have been quantified to develop a new generation model for melon growers in Texas to schedule optimal harvest times. In addition, a soil process simulator for plant models was developed for the Web and has been used in a number of studies in Israel, Germany, Russia, England, and Taiwan. Soil process simulation models and model based data analysis have also been used to estimate ground-water recharge for the Nuclear Regulatory Commission to provide guidance to NRC contractors for accepted monitoring methods of ground-water. Simple water budget models have been useful to analyze yield map data and remotely sensed information on leaf area index. This research benefits agricultural managers, scientists, and policy makers interested in quantifying environmental factors on crop growth and yield. **ARS Locations & Cooperators:** Beltsville, Prosser, Ft. Collins, Riverside, Mississippi State University, and the University of Maryland. **Selected Refereed Publications:** Kim et al., 2003. Kim et al., 2004. Kim et al., 2006. Timlin et al., 2002.

Agricultural system-level models used to help direct field research. The agricultural system model Root Zone Water Quality Model (RZWQM) provides a systems approach for field scientists to simulate various producer management practices. Over the last five years, several improvements have been made linking RZWQM with DSSAT (CERES and CROPGRO) plant growth models to provide users more options in plant growth simulation. Also, RZWQM and SHAW have been integrated to simulate no-tillage effects on soil moisture and temperature, and with the GIS application *Maria* to extend applications to spatially distribute field results. RZWQM has been used to simulate the effects of weather variability, controlled drainage, and cover crop components on soil and water quality. **ARS Locations & Cooperators**: Fort Collins and Colorado State University. **Selected Refereed Publications:** Hu et al., 2006. Ma et al., 2005. Ma et al., 2006. Malone et al., 2004. Nielsen et al., 2002. Yu et al., 2006.

Generic interface for crop simulation models simplifies model use for growers and scientists. Graphical user interfaces simplify the use of simulation models and data management by users. The graphical user interface GUICS was developed for on-farm use by growers in the Mississippi Delta and the Florida Panhandle to test the soybean model GLYCIM. In addition to GLYCIM, several other models were added to GUICS, including MAESTRA, a model of tree crop growth useful for Nursery Managers, GOSSYM, a mechanistic cotton model, SIMPOTATO, a model of potato growth, and MELONMAN, a management model for melon crops. We have had over 100 requests for the software and have distributed it widely in the United States and internationally via the Web. **ARS Locations & Cooperators:** Beltsville, Mississippi State University, Clemson University, and University of Maryland. **Selected Refereed Publications:** Anbumozhi, et al., 2003. Bauerle et al., 2005. Taylor et al., 2004.

Web-based planning tools for conservation managers. An integrated Web-based conservation planning tool platform linked to a relational database and served by a Web-based geographic information system map browser was developed. Automated conservation planning worksheets were made available to the NRCS State Office in

Portland. Oregon NRCS estimated their conservation planners save 200 hours of planning time annually through use of automated worksheets. The Online Agriculture Conservation (OAC) Planning Tool Box was delivered to the Yolo County (CA) Resource Conservation District to evaluate conservation education activities. WebGRMS (Germplasm Management System) software emulating the USDA Genetic Resources Information Network (GRIN) database demonstrated germplasm managers can easily make geospatial analyses of germplasm collections without GIS software training using low-cost, open-source Linux operating system software. WebGRMS software emulating the USDA GRIN database was also delivered to the USDA-ARS Plant Germplasm Introduction and Testing Unit at Pullman. NRCS headquarters and the State Office in Portland are collaborating in the development of a landowner self-assessment Web tool to support Conservation Security Program delivery by all state offices. **ARS Locations & Cooperators**: Corvallis and Oregon State University Department of Electrical Engineering and Computer Science. **Selected Refereed Publications:** Steiner et al., 2005. Steiner et al., 2006.

Problem Area C. Strategies to Expand Market Opportunities.

1. Producing Organic Products. Organic production is one of the fastest growing segments of U.S. agriculture with sales greater than $12.8-billion that are increasing more than 20% annually. Increased research efforts by ARS are needed to see to it that production keeps pace with increasing American and world consumer demand for organic products, and to ensure the food product safety. ARS has an established nation-wide network of research facilities that can address all aspects of organic food, feed, and fiber production for all U.S. production regions and consumer markets.

Manure use can be managed to benefit soil biodiversity and reduce potential health risks. Organic systems rely heavily on recycling nutrients to crops from animal manure and soil organic matter. These same nutrients can be sources of ground and surface water contamination. Use of manure in organic vegetable systems is a concern due to the potential for contamination by human pathogens in the manure. ARS researchers found that *Listeria monocytogenes* (a major gastrointestinal pathogen) present in liquid dairy manure did not survive in soil beyond 70 days after field application, and was not present on potatoes harvested from the same soil. **ARS Locations & Cooperators:** Orono, Maine Organic Farmers and Gardeners Association, Northeast Organic Dairy Producers Alliance, Maine Organic Milk Producers, University of Maine, University of New Hampshire, University of Vermont, Agriculture and Agri-Food Canada, University of South Carolina, Brookhaven National Laboratory, Savannah River Ecology Laboratory, Stanford University, University of Delaware, Alabama A&M University. **Selected Refereed Publications:** Larkin et al., 2006. Liao et al., 2003.

Improved understanding of disease management in organic potato systems helps all producers. Plant diseases are significant problems in many organic production systems. It was demonstrated that oregano completely inhibited growth of the Late Blight pathogen (*Phytophthora infestans*) in the laboratory and partially inhibited the pathogen in growth chamber studies. Also, commercially-available biological control organisms such as *Trichoderma virens* and *Bacillus subtilis* can reduce Rhizoctonia stem canker by 37-75% and black scurf by 11-20%, while increasing potato yield by 15-20%. Similarly, crop rotations of *Brassica* species reduced several diseases on potato. This research identified several options for controlling diseases that are now employed by both organic and conventional growers. **ARS Locations & Cooperators**: Orono, Auburn, Beltsville, Bowling Green, Clay Center, Lincoln, Madison, Pendleton, Tifton, Wyndmoor, University of Maine, University of New Hampshire, University of Vermont, Agriculture and Agri-Food Canada, University of South Carolina, Brookhaven National Laboratory, Savannah River Ecology Laboratory, Stanford University, University of Delaware, Alabama A&M University. **Selected Refereed Publications**: Larkin, 2002. Larkin, 2006.

Organic management practices and soil biological responses. Organic strawberry production did not benefit from mycorrhizal inoculants, although mycorrhiza induced earlier maturity in tomato and may benefit onion, watermelon, and pepper. Because of the multiple ecosystem services provided by soil macro-organisms, understanding the impact of cropping systems on the abundance and species diversity of soil macro-organisms could help in designing cropping systems that are less dependent on pesticides to regulate pest species numbers and activities. Ground beetle relative abundance, species number, and species diversity were greater in an organic cropping system than in a conventional chisel-tilled system. Ground beetle assemblages were very similar in no-till and chisel-till systems, and were most unique in organic cropping systems. This research is of particular interest to organic farmers who consider soil biological activity an important component of their production system, but do not have scientific information directing their management decision concerning soil biological communities and their effects on productivity. **ARS Locations & Cooperators:** Beltsville, Salinas, Community Alliance for Family Farmers, California Strawberry Commission, University of California. **Selected Refereed Publications:** Bull et al 2004.

Organic alternatives for deworming sheep and goats. Internal parasites of sheep and goats are becoming resistant to chemical dewormers and organic producers cannot use chemical treatment. Genetic resistance against parasites was found a viable approach for parasite control, with St. Croix and Katahdin hair breeds being more resistant to parasites than Dorper and other wool breeds. Preliminary results suggest small ruminants ingesting sericea lespedeza, a condensed tannin-rich forage, had lower populations of the *Haemonchus contortus* internal parasites. Supplementation with low doses of copper oxide wire particles appeared to be an effective means to control *Haemonchus* infestations in small ruminants. Management protocols that permit only low levels of internal parasites are essential for organic sheep and goat meat production systems. Further component and system level research is required to solve problems related to organic production of small ruminants. **ARS Locations & Cooperators:** Booneville, Southern Consortium for Small Ruminant Parasite Control, and University of Arkansas. **Selected Refereed Publications:** Burke et al., 2002. Burke et al., 2004. Burke et al., 2006. Shaik et al 2006.

Increasing crop rotation length and complexity reduces weed pressure and increases crop yields in organic systems. Organic farmers have identified weed management as one of their biggest challenge. In a ten-year study on weed dynamics in organic and conventional systems, the impacts of weeds on crop yields and weed seed bank size in corn and soybean decreased as crop rotation length and complexity increased from one to five years. Weed seed bank size in the spring was often correlated with weed cover percentage at maturity the same year, demonstrating that maintaining a low seed bank by using diverse rotations can lead to improved weed control in organic crops. During favorable years, corn yield losses due to weeds were less than 5% in the longest organic rotation, a level similar to that achieved using herbicides in conventional no-till and chisel-till systems. This result indicates that with good management, longer organic crop rotations can function comparably to conventional systems. These results will be of great benefit to organic farmers and those considering transitioning to organic cropping when they plan their weed control strategies. This research has resulted in the establishment of a Congressionally-mandated cross-location research project with Pennsylvania State University and the Rodale Institute to conduct a comprehensive analysis of weed population dynamics in conventional and organic systems. **ARS Locations & Cooperators**: Beltsville, Rodale Institute, Pennsylvania State University. **Selected Refereed Publications**: Teasdale et al., 2003. Teasdale et al., 2004.

First Low-Soil Disturbance Organic Cropping System Designed and Tested in Pacific Northwest

Organic farming systems have historically relied on intensive tillage to establish crops and manage pests. In the Pacific Northwest, the severe hazard of soil erosion precludes the use of intensive tillage in the design of sustainable cropping systems. A low soil disturbance organic system was designed and field-initiated in 2001 at the Palouse Conservation Field Station. The new organic system, implemented at field-scales, combines recent no-tillage technology with key cropping system elements to meet national USDA Organic standards as well as regional biophysical constraints and economic objectives. After four years, we show that the integration of no-tillage with organic technologies is viable and represents a nascent accomplishment as the system is continually modified and improved each year. Notable system constraints are primarily fertility related and the system has been improved to include more legumes. Several farmers have now initiated conservation tillage-based organic systems and represent the first farmers to attempt this in the dryland cropping region of the Pacific Northwest. **ARS Locations & Cooperators**: Pullman and Washington State University, Pullman, WA. **Selected Refereed Publications**: None.

Cover cropping practices improve organic weed management. Weed management is challenging and expensive in organic crop production. Because it is essential to minimize weed seed production during all phases of a crop rotation, the relationship of biomass from common winter cover crops including cereals, mustard, and legume/oat mixtures on season-long weed suppression was determined. Within a site, there were few differences in above ground biomass production by the cover crops, but large differences in their weed suppressive abilities. Weed suppression was influenced by seeding rate and cover crop variety. At typical seeding rates, weed suppression was excellent by mustard and rye, intermediate for oats, and extremely poor in legume/cereal mixes. Increasing the seeding rate of the legume/cereal mixes improved weed suppression to acceptable levels. An additional trial found that the rotary hoe could reduce weed seed production in winter cover crops by up to 80%. This research benefits organic producers by providing information that has helped maximize the benefits of cover cropping and minimize weed seed production in high-value vegetable crops throughout the year. **ARS Locations & Cooperators**: Salinas, California Cooperative Extension. **Selected Refereed Publications**: Brennan and Smith, 2005.

Factors of organic production affect cover crops and vegetables. Vegetable production systems that conform to organic requirements for Oklahoma are being developed from transplant production time to harvest. The transition period to organic production was examined for three vegetables. Over time yields increased during the transition period to organic production, but inputs requirement remained the same or increased, thus reducing profit. Trials examining use of corn gluten meal for weed control in non-pungent jalapeno determined that although there were initial reductions in weed densities, there were no observable reductions in weed densities or differences at harvest, compared to the weedy-check treatments. The certified organic watermelon production system using plastic mulch rather than acetic acid for weed control had greater weed control and watermelon yields. The scientists are working closely with local organic producers, and portions of the systems are being adopted. The Lane location has the first certified organic acreage in the state of Oklanhoma. **ARS Locations & Cooperators**: Lane. **Selected Refereed Publications**: Russo, 2005.

Stale seed bed techniques for organic vegetable production. High-value organic vegetable crop weed management has hand labor costs up to $1500 per acre. This high cost and increasing legislative pressure limiting use of weeding labor necessitates the development of techniques that minimize hand labor for weed control. ARS scientists in California collaborated with a local organic farmer to evaluate the effectiveness and cost of six organic compliant weed management tools to prepare stale seed beds in high-density vegetable production. These techniques included organic herbicides, propane flamers, and various cultivation tools. Most techniques controlled more than 70% of the weeds and cost less than $230 per acre. However, the organic herbicide was ineffective and cost $1557 per acre. These findings identified effective methods to help organic producers minimize the need for hand weeding of high value vegetable crops. **ARS Locations & Cooperators**: Salinas, Tanimura and Antle Corporation, and University of California. **Selected Refereed Publications**: Boyd et al., 2005.

Modified crops for use in organic production systems. Crops sometimes need to be specifically tailored for use in high-value organic systems. Conventional grain-type soybeans fail to provide adequate crop residue to control soil erosion. Therefore, a six-foot-tall, lodging-resistant soybean cultivar named Tara was bred and released to farmers. Tara provided 72% more crop residue after grain harvest than conventional cultivars, and is now being used by farmers on several thousand acres. Moon Cake, a new dual use vegetable soybean cultivar, was bred and released to farmers for fresh green seeds to provide a vegetable protein for human consumption, and for stover after seed harvested that can be fed to livestock. The six-foot-tall Moon Cake enables it to compete against weeds. **ARS Locations & Cooperators:** Beltsville. **Selected Refereed Publications:** Devine et al., 2004.

Organic log-grown shiitake mushrooms contain health-promoting polysaccharides. There are two major production systems for shiitake mushrooms. Log-grown shiitake meets the standards for organic agriculture, but production costs are greater than substrate-grown mushrooms. Customers may be more willing to pay more for log-grown shiitakes if these mushrooms can be marketed as a food that has health-promoting effects beyond its nutritional value. Shiitakes are known to contain a polysaccharide that has been shown to promote human health. Cooperative research by ARS scientists showed that the content of this polysaccharide was at least twice as high in log-grown shiitake, and both spawn source and tree species influenced polysaccharide content. These results are of interest to shiitake mushrooms growers interested in promoting their product to consumers of healthy food products. This is a maturing accomplishment. Further research is needed to fully characterize effects of management on health promoting constituents. **ARS Locations & Cooperators:** Booneville, Shirley Community Development Corporation. **Selected Refereed Publications:** Brauer et al.., 2002

2. Integrating agricultural-based energy production. Crops specifically grown for energy production and left over straw and manure from agricultural operations are a part of the estimated 1.3-billion tons of biomass available in the U.S. that could be used to produce energy. Research is needed to incorporate small-scale thermal-chemical conversion technologies that can be used to produce energy from biomass and manure waste and directly generate additional revenue stream on the farm.

Sustainable production of bio-fuel crops. Experiments in eastern Washington demonstrated a variety of oilseed crops could be grown as feedstocks for a biodiesel industry, and ligno-cellulose reserves from wheat straw, corn stover, and switchgrass could be utilized for ethanol production. Results indicate that to support a 5-million gallon biodiesel facility, the land area required ranges from 35-100,000 acres, depending on the oilseed crop grown. Canola or rapeseed were determined to be the best crop selections because of their high oil content, ability to fit into both dryland and irrigated crop rotations, and that farmers currently maintained the necessary agricultural equipment. Mustards, soybeans, and safflower oilseeds could be used in rotations for crop diversification, as well as oilseed markets. For ethanol production 30-60,000 acres of switchgrass, wheat straw, or corn stover would be necessary to support a 20 million gallon ethanol facility. Twelve biodiesel and ethanol facilities with annual production capacities of 30-M gallons biodiesel and 290–M gallons of ethanol have been proposed for the Columbia Basin of Washington and Oregon. This research is integral to estimate economic thresholds for feedstock resources in the development of a sustainable biofuels industry in the Columbia Basin. **ARS Locations and Cooperators**: Prosser and Washington State University. **Selected Refereed Publications:** none

Technology development for farm–scale conversion of straw to energy. Historically, much of the straw produced from Pacific Northwest grass seed and cereal grain cropping systems was treated as waste because of limited markets for this excess residue. The high cost of transporting straw to centralized conversion facilities has plagued previous value-added strategies. To overcome this barrier, researchers evaluated the potential for the on-farm conversion of straw to energy. A new gasifier designed appropriately for on-farm use, was developed and tested utilizing Kentucky bluegrass straw. The unit converted straw into synthesis gas without slagging, a problem that has limited previous thermochemical technologies. This successful proof of concept will be used to develop a second-phase gasifier where the economic feasibility of converting straw to energy can be evaluated on farm. Conversion of the excess 7-million tons of straw beyond conservation requirement into liquid fuels could yield more than 420-million gallons of mixed alcohol valued at $840-million. **ARS Locations & Cooperators:** Corvallis, Eastern Regional Research Center, and Western Research Institute. **Selected Refereed Publications:** Boateng et al., 2006. In press

3. New Products from Agricultural Lands. There are four accomplishments in this problem area. Two are related to increased use and better management of silvopastures for improving productivity and opening new market alternatives. Another accomplishment examined the use of technology to lengthen the growing season for high-valued crops and thus increase the marketing season for producers in the region. The fourth accomplishment increased the research capacity to identify constraints to increased productivity and profitability in both conventional and organic systems.

Important criteria defined for the design and management of temperate silvopasture practices. More than 20% of beef cattle in the U.S. (22.5 million head) are raised in the lower Midwest United States. The region has more than 62.9 million acres of private pasture that engages over 312,000 farm families. Equal numbers of beef cattle are born or spend at least a portion of their lives on pastures in the southeastern United States. Many family farms also have significant acreages of wood lots, so adoption of silvopasture has been advocated as a means to increase the productivity of these resources. Understanding has been gained of how to design and manage silvopastures to increase productivity and profitability. The microclimate effect of pine trees in a silvopasture stimulates early spring forage growth that allows livestock producers to place cattle on pastures two-to-three weeks earlier than on open pasture. Similarly, grazing in silvopastures can be extended two-to-three weeks later in the fall. These results indicate that well-managed silvopastures can reduce winter feed costs in the lower Midwest by approximately 20%. Orchardgrass, or a binary mixture of orchardgrass and tall fescue, had better growth, persistence, and feed quality than tall fescue in the shade of loblolly pine alleys, while a tall fescue monoculture was more productive in the unshaded environment. The spacing of loblolly trees on a marginal site affected forage yield, nutritive value, and botanical composition of a bermudagrass and tall fescue mixture within 7-8 years after planting. Results from several different experiments indicate that a two row configuration is optimum for timber production in southern pine silvopasture, however, partitioning of biomass to the tree bole for timber production may be less in agroforestry systems compared to traditional forestry production systems. Economic analyses indicate that the profitability of pecan silvopasture practices of the Midwest United States is derived primarily from pecan nut sales. There are substantial opportunities to increase the profitability of this practice by marketing the timber from tree thinning. While nut yields of eastern black walnut trees in a stand vary considerably, future yields can be predicted. These results have added considerably to the knowledge of the design and management of silvopastures. This knowledge needs to be combined with forthcoming results for the development and dissemination of site-specific best management practices for silvopastures. **ARS Locations & Cooperators:** Booneville**,** Kansas State University, University of Missouri-Columbia, Mississippi State University. **Selected Refereed Publications:** Burner et al., 2003a. Burner et al., 2003b. Burner et al., 2004. Ares et al., 2005. Ares et al., 2006.

Eastern red cedar and chestnuts are attractive alternative crops for small farmers. Crops that are in high demand and command high prices are good alternative crops for small farms. Chinese chestnut can begin bearing commercial quantities of nuts 6-10 years after planting with 1,000-1,500 pounds of nuts per acre easily attained. Current wholesale prices range from $1.60-6.00 per pound. In addition over 80% of current American supply is from foreign markets, so this presents a ready domestic market. A national market survey of eastern red cedar has shown that this species, formerly viewed as a "trash" tree, has an expanding national market valued in excess of $60-million. These results indicate the potential of increasing the profitability of small farms by the production of high value alternative crops. **ARS Locations & Cooperators:** Booneville, University of Missouri. **Selected Refereed Publications for this Accomplishment: Selected Refereed Publications:** Gold et al., 2004. Gold et al., 2005a. Gold et al., 2005b.

Cuphea as a new oilseed crop for Northern Corn Belt. Additional economically viable crops are needed that can be grown in rotation with corn and soybeans to help break weed and pest cycles and diversify farming operations. The U.S.A. currently imports over a billion pounds of coconut and palm kernel oils each year for use in making soaps, detergents, personal care products, nutritional and dietetic products, and lubricants. Domesticated cuphea could serve as a substitute for these and serve as a replacement for certain high-value petroleum-based lubricants. Cuphea fits well in a corn-soybean-wheat rotation following either soybean or wheat. Additionally, corn yield may benefit when following cuphea. In 2004, in collaboration with industrial partners, ARS scientists successfully took cuphea to on-farm commercialization on 50 acres. In 2005, 100 acres were grown, and over 400 acres have been contracted for 2006. Industrial demand for cuphea oil is high enough that hundreds of thousands of acres could be produced in the near future. **ARS Locations and Cooperators:** Morris, Technology Crops International, Proctor and Gamble Company, Minnesota Department of Agriculture, and Western Illinois University. **Selected Refereed Publications:** Gesch et al., 2005. Forcella et al., 2005. Forcella et al., 2005. Olness et al., 2005. Sharratt et al., 2004.

Small-Scale Farmers Can Receive Income from Pine Straw Without Increasing Soil Erosion. Pine straw harvesting can provide an additional income source to small farms. However, there are concerns that removal of pine straw will increase soil erosion. Experiments conducted by the ARS Dale Bumpers Small Farms Research Center, Booneville, Arkansas, showed how pine straw could be harvested without increasing soil erosion. It was demonstrated that when pine straw is harvested once every three years, precipitation run off, soil erosion amount, and nutrient losses were not affected. This finding benefits landowners looking for additional income sources as well as conservation planners interested in helping these farmers. **ARS Locations and Cooperators:** Booneville. **Selected Refereed Publications:** none**.**

High tunnel research capacity established to serve mid-Atlantic small farmers. Small farmers near urban areas successfully compete by targeted direct market strategies that supply unique or superior quality products or optimize production timing for high prices. Although high tunnels have been used in northern areas for several years, mid-Atlantic growers have discovered tunnels can provide advantages of extending the growing season and enhancing product quality, despite the relatively mild climate in this region. Houses with and without use of selective plastic that block the transmission of solar ultraviolet radiation below 380 nm have been established to determine how these optical properties impact crop and pest management. Collaborative studies have demonstrated the enormous potential of using high tunnels for production of high value crops that can extend the growing season by 4-6 weeks in both the spring and the fall. Results and recommendations are shared with other farmers through field days and our winter regional conference with the expectation that high tunnel use will rapidly expand throughout the area. **ARS Locations & Cooperators:** Beltsville, Maryland Extension and SARE. **Selected refereed publications:** Gonzalez-Aguilar et al., 2001. Krizek et al., 2001. Krizek, et al., 2004. Krizek et al., 2005. Middleton et al., 2005.

RESEARCH GOAL III. PROTECTED AND ENHANCED NATURAL RESOURCES ON FARMS

Many landowners are recognizing the importance of describing the quality of water and wildlife habitat associated with their farms. There are several ARS units involved in natural resource research where agricultural practices impact water ways and wildlife habitats. These investigations provide a starting point to increase awareness of the importance of wildlife resources in agriculture.

Use of remote sensing and ground-truth surveys to monitor soil disturbance and land use patterns across landscapes. ARS scientists in Corvallis developed a combination ground-truth survey and remote-sensing approach to create a public geographic information system database of grass seed cropping practices and stand establishment patterns in Linn County, Oregon. A multi-step classification procedure using Landsat images to spatially and temporally extend the database based on major land use categories verified by a ground-truth census that showed the remote sensing method to be 74% accurate. The GIS was used to characterize differences in soil disturbance patterns among sub-basins of the Calapooia River watershed, revealing the presence of a 3-fold range in proportion of agricultural land tilled each year. Information on stand establishment and tillage practices across the landscape is vital because our previous research had demonstrated that tillage practices, rather than riparian buffers, had greater impact on transport of sediments and nutrients in western Oregon streams. Spatially-explicit quantification of soil disturbance patterns will be a critical input to the Soil and Water Assessment Tool model under development for landscape-level optimization of conservation practices, crop production, water quality, and biological indicators of ecosystem services. **ARS Locations & Cooperators**: Corvallis. **Selected Refereed Publications**: none.

Identifying management practices that optimize economic and environmental benefits at the watershed scale level. An integrated modeling system to provide farmers, conservation planners, and policy makers a set of solutions that optimize economic conservation practice selection was developed. This accomplishment is important because the modeling system provides documentation on the effectiveness of water quality conservation practices supported by the Conservation Title in the USDA Farm Bill. A working prototype, based on the results of replicated field trials, used a genetic algorithm to integrate use of the ARS Soil and Water Assessment Tool (SWAT) with an economic model. The system was applied to a test watershed in western Oregon and will be used for the 13 watersheds in the national USDA *Conservation Effects Assessment Project*. This research provides a new method to optimize multiple conservation and economic objectives and is an important component of assessment of USDA conservation programs at the national level. **ARS Locations & Cooperators**: Corvallis, Temple, Oregon State University. **Selected Refereed Publications:** Whittaker et al., 2003.

Wildlife habitat impacts agricultural drainage water to constructed wetlands. Do wetlands that are constructed in rural landscapes to receive and treat agricultural runoff and drainage water provide effective wildlife habitat? To answer this question, this work studied the development of vascular vegetation and periodically inventoried the terrestrial and aquatic ecology of three constructed wetlands in Northwest Ohio receiving runoff and drainage water from corn/soybean production systems. Hydrophytic vegetation within the surrounding landscape provided an adequate source of seed stock to achieve approximately 50 % wetland species in each basin 5 years after construction without planting or seeding. Numbers and types of both terrestrial and aquatic wildlife species increased with time after construction at each wetland. Wetland site designers and managers, NRCS, and Extension professionals, rural residents, and the general public all benefited from these findings through evaluation of current practice effectiveness, improved design and management guidelines, and creation of additional wildlife habitat in the agricultural landscape. **ARS Locations & Cooperators:** Columbus, Ohio State University, and University of Findlay. **Selected Refereed Publications:** Luckeydoo et al., 2002. Luckeydoo, 2004.

Importance of considering environmental impacts of drainage ditch management. Drainage ditches are a common component of many agroecosystems in the eastern United States. Historically, ditches have been managed for the single purpose of draining excess water from agricultural fields without regard for the ecological impacts these management actions. Research began in 2005 to determine the influence of grassed buffers and farming practices on the physical habitat and aquatic communities within agricultural drainage ditches. Initial findings have documented that drainage ditches serve as important habitats for fishes within agricultural watersheds, and suggest that incorporation of environmental considerations into the management of ditches will benefit the fishes within these systems. Also, those conservation practices that alter ditch hydrological characteristics will have the greatest impact on fishes and other aquatic animals. This research will be valuable for state agencies, federal agencies, and environmental groups responsible for funding and assisting producers with installing grassed buffers, implementing nutrient management practices, and implementing pesticide management practices through USDA Farm Bill programs. The results will also provide producers information to consider to manage ditches as multi-purpose systems designed to provide habitat for aquatic animals and drainage of agricultural fields. **ARS Locations & Cooperators:** Columbus, Ohio State University, Purdue University, Upper Big Walnut Creek Water Quality CEAP-SWPI, Ohio Department of Natural Resources, and Rural Drainage Ditch Advisory Committee. **Selected Refereed Publications:** none.

Grass seed farming landscapes provide excellent fish and wildlife habitat. Farm aquatic and terrestrial habitats protect many fish and wildlife species, and thus serve as a valuable resource worthy of enhancement and protection. It was found that native fish and amphibians utilized seasonal streams, originating from western Oregon grass seed fields, as refugia during the winter high flow periods. Water quality nutrient constituents were found to be at ranges not harmful to aquatic biota. Winter bird abundance and diversity was correlated with the percent of tree cover along drainages in the south Willamette River basin, OR. Surveys demonstrated that seventeen-times more birds were found along forested than non-forested drainages, but only 15% of the total land cover needed to be in trees to maximize songbird richness. Using bird behavior findings and knowing that 70% of the watershed land area is less than optimal, farmers can now know where to target USDA conservation projects to optimize economic and environmental benefits. These studies provide the first-of-its-kind comprehensive information showing how managed upland agricultural landscapes in watersheds are places where species listed under the Endangered Species Act can flourish during seed production cycles. **ARS Locations & Cooperators:** Corvallis, Oregon State University, University of Massachusetts, USDA-NRCS, and local farmers. **Selected Refereed Publications:** McComb et al., 2005. Banowetz et al., 2006.

Management schemes for alley cropping practices improve dove habitat. There are substantial opportunities at the rural-urban interface for farmers to increase their profitability by managing their landscape for game species and charging fees for hunting access. Mast-bearing trees alley cropped with sunflowers is an attractive management option to farmers interested in dove lease-hunting. Missouri has 40,000 dove hunters who spend $5-million annually, and demand is increasing. Components important to development of management protocols for enhancing dove habitat are being investigated. Swamp white oak seedlings produced from acorns in large containers will bear acorns within 18-30 months, in contrast to 15-30 years for natural oak stands. Effective and substantial weed control was found to be critical to establishment of hardwood plantations, especially in the floodplains of major rivers. Establishing oak seedlings in former bottomland crop fields with a cover crop of redtop grass will prevent rabbit damage and produce 98% survival four years after outplanting. The spring growth and short stature of the redtop grass prevents the growth of other competitive understory vegetation and is a poor habitat for rabbits. These results provide a framework for successful alley cropping practices to establish oak seedlings to increase dove habitat and increase farm profitability via hunting lease fees. These results need to be transferred to landowners to increase adoption of such practices in the Midwest region of the United States. This accomplishment has focused primarily on system components to date. Additional component research is needed, including system level analyses. Future technology transfer activities will be required for the research to have full impact. **ARS Locations & Cooperators:** Booneville, Missouri landowners, U.S. Forest Service, NRCS, and University of Missouri. **Selected Refereed Publications:** Grossman et al., 2003. Ares and Brauer, 2004. Kabrick et al., 2005.

Peer Review Publications

1. Abdul-Baki, A., Bryan, H.H. Klassen, W. and Codallo, M. Propagation and establishment of perennial peanuts for ground covers along roadsides and highway ramps. Proc. Fla. State Hort. Soc. 115:267-272. 2002.
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