FY 2007 Annual Report
National Program 211 - Water Availability and Watershed Management

Introduction

Water is fundamental to life. It is a basic requirement for virtually all of our agricultural, industrial, urban, and recreational activities, as well as for the sustained health of our natural ecosystems. As Earth's human population tripled during the last century, demand for Earth's finite supply of available fresh water increased six-fold. The United Nations estimates that more than a billion people live without access to clean water, and more than 2.4 billion people lack the basic sanitation needed for human health. The U.S. Environmental Protection Agency has estimated that it will cost in excess of $150 billion to provide clean and safe water to the Nation. Shortages of fresh water—already evident in the drought-ridden western United States—cost the Nation in excess of $8 billion per year in addition to untold environmental impacts. When only freshwater withdrawals are considered, agriculture is clearly the largest user of water in the United States; thus agriculture has the greatest opportunity to conserve water supplies and improve water quality through scientific discovery.

The goal of the USDA/ARS Water Availability and Watershed Management National Program is to manage water resources effectively and safely, while protecting the environment and human and animal health. This goal will be achieved by characterizing potential hazards, developing management practices, strategies and systems to alleviate problems, and providing practices, technologies and decision support tools for the benefit of customers, stakeholders, partners, and product users. Research in this National Program addresses six component problem areas: (1) the effectiveness of conservation practices; (2) irrigation water management; (3) drainage water management systems; (4) integrated soil erosion and sedimentation technologies; (5) watershed management, water availability, and ecosystem restoration; and (6) water quality protection systems.

The mission of this National Program is twofold: (1) to conduct fundamental and applied research on the processes that control water availability and quantity for the health and economic growth of U.S. citizens; and (2) to develop new and improved technologies for managing the Nation's agricultural and water resources. Advances in knowledge and technologies provide producers, action agencies, local communities, and resource advisors with the practices, tools, models, and decision support systems they need to improve water conservation and water use efficiency in agriculture, enhance water quality, protect rural and urban communities from the ravages of drought and floods, improve agricultural and urban watersheds, and prevent the degradation of riparian areas, wetlands, and stream corridors.

ARS, in cooperation with the Natural Resources Conservation Service, the Cooperative State Research, Extension, and Education Service, the Environmental Protection Agency, and other Federal and State agencies, has developed a watershed research program called the Conservation Effects Assessment Project (CEAP). The purpose of CEAP is to provide a methodology for documenting the national and regional environmental effects and benefits obtained from USDA conservation program expenditures, and inform choices on how to achieve maximum benefit from those expenditures. During FY2007, ARS developed a data storage and management system called STEWARDS (Sustaining the Earths Watersheds Agricultural Research Data System) to house data collected as part of the CEAP assessment for croplands, drafted a retrospective review describing ARS accomplishments related to the CEAP assessment for croplands, to be published in a special issue of the Journal of Soil and Water Conservation in 2008, extended the CEAP cropland assessment to tropical environments through the establishment of a Special Emphasis Watershed in Jobos Bay, Puerto Rico, and expanded CEAP activities to the assessment of grazinglands and wetlands.

The National Program Staff continues to coordinate ARS water resource related activities with regional, national, and international partners. A milestone of ARS CEAP activities during FY2007 were the sessions held in association with Soil and Water Conservation Society's 2007 Annual Conference, held July 21-25, 2007, in Tampa, FL. The conference featured a plenary presentation by ARS Administrator Dr. Edward Knipling on the significance of CEAP from an ARS perspective, 63 formal contributed papers presenting the results of the ARS-CEAP Watershed Assessment Studies, 23 ARS poster presentations, and working group meetings for each of the 6 ARS CEAP management teams. The proceedings of this conference are available through the Soil and Water Conservation Society's web site: http://www.swcs.org/.

The National Program Staff coordinates with other government agencies to leverage agency resources through its active participation in a variety of intergovernmental committees including: (1) the Committee on Environment and Natural Resources (CENR) (the relevant National Science and Technology Council committee for water research) Subcommittee on Water Availability and Quality (SWAQ), a subcommittee within CENR devoted to water issues that serves as a forum for agency representatives to share information about their respective programs; (2) the National Agricultural Research, Extension, Education and Economics (NAREEE) Advisory Board, which evaluates USDA Research and Development Programs and provides recommendations to the Secretary and REE Undersecretaries; (3) the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, charged by Congress with conducting a reassessment of (i) nutrient load reductions and the response of the hypoxic zone, (ii) water quality throughout the Mississippi River Basin, and (iii) economic and social effects, a draft of which is currently being circulated for public comment (4) the Advisory Committee on Water Information (ACWI) Subcommittee on Sedimentation; (5) the USDA Drought Team and the Working Group on Water Resources; and (6) the Conservation Effects Assessment Project Steering Committee, among others.

Selected Accomplishments:

Problem Area 1—Effectiveness of Conservation Practices

A new remote sensing technique to estimate nutrient uptake by cover crops. Cover crops have been shown to be an effective way to reduce nitrogen losses from agricultural fields, but are difficult to monitor at the watershed/landscape scale. ARS researchers in Beltsville, MD, developed a remote sensing technique to estimate the amount of N sequestered in cover crop biomass on farms enrolled in State cover crop cost share programs. The pilot study was conducted in the Choptank River watershed in MD, part of ARS' watershed research network associated with the Conservation Effects Assessment Project (CEAP). The technique will allow managers to optimize and efficiently monitor this important best management practice at watershed and regional scales with the aid of remote sensing that is non-invasive.

Improvements in riparian area modeling for water quality assessment. Accurate modeling of water movement through riparian buffers is critical for watershed-scale water quality assessments. ARS scientists at Beltsville, MD, and Tifton, GA, tested the Riparian Ecosystem Management Model (REMM) using a GA riparian database. The sensitivity of REMM nutrient and sediment output was quantified with respect to changes in key riparian buffer parameters (e.g., vegetation; soil characteristics). Parameters associated with vegetation (e.g., rooting depth; plant height) moderately affected nutrient and sediment yields, but outputs were highly sensitive to changes in physical parameters (e.g., slope; Manning's surface roughness coefficient). Scientists at Beltsville are developing a similar evaluation of REMM for the Choptank SEW. This new model will assist farmers and policy makers in quantifying the effectiveness of specific riparian buffers in reducing pollutant loads to streams and other surface waters.

A new management practice for reducing nitrate loss in drainage waters. Nitrogen losses from agricultural fields are an important contributor to the eutrophication of Chesapeake Bay. Best management practices aim to reduce N losses, thereby improving water quality. In the Choptank River Special Emphasis Watershed (SEW), MD, excess nutrient transport from agricultural fields is primarily through extensive open drainage ditches, where on average, 6% of the nitrate applied annually may be transported to streams, rivers, and eventually the Chesapeake Bay. One of the best management practices (BMPs) used in these ditches is the installation of water control structures at the drainage outlet to reduce water flow and nutrient loss. Preliminary studies indicate that increasing water table elevation to just below the root zone during the growing season, while lowering it during planting and harvesting operations, can reduce nitrate losses up to 40%. These findings provide quantitative efficiencies for both water and nitrate reductions, and better management strategies for more efficient use of controlled drainage BMPs.

Development of a river basin scale water quality model. Simulation models are critical to the accurate assessment of water quality concerns and the effects of conservation practices aimed at improving water quality. ARS scientists at the Grassland, Soil and Water Research Laboratory, Temple, TX, have developed a river basin scale model called SWAT (Soil and Water Assessment Tool) that integrates hydrology, soil erosion, plant growth, and nutrient cycling, with off-site processes such as channel erosion/deposition, pond and reservoir processes, groundwater flow, and climate variability. Numerous interfaces have been developed for the model to assist users in obtaining model inputs and interpreting model outputs. The model was calibrated and validated, and uncertainty in its output was analyzed, based on observations from the CEAP Benchmark Watersheds and other watersheds around the world. In general, the model compared well with observed stream flow and sediment and nutrient loads and concentrations. The model is being used across the country by US EPA to assess water quality concerns, and by USDA to assess the environmental impact of conservation programs on water quality and quantity. Scientists around the world are contributing to model development; over 350 scientific papers have been published in the open literature on the development and application of SWAT.

Data and information from ARS Watersheds are assembled to address National research and conservation needs. Vast quantities of scientific data are collected annually in the US, but the benefits of such data collection activities are not fully realized unless these datasets are stored and maintained for integrative analysis and potential future use. ARS researchers and staff from El Reno, OK, Columbia, MO, Beltsville, MD, Ames, IA, and Fort Collins, CO, developed a web-based data system—Sustaining the Earth's Watersheds, Agricultural Research Data System (STEWARDS)—that organizes and documents soil, water, climate, land-management, and socio-economic data from multiple agricultural watersheds across the US, allowing users to search, download, visualize, and explore data for research and conservation management purposes. STEWARDS is currently being beta-tested by the CEAP research team. When released to the public, STEWARDS will help: 1) researchers obtain ARS' long-term data for hydrological studies; 2) modelers retrieve data for model calibration and validation; and 3) watershed managers and a wide array of partners and stakeholders access long term data to support conservation planning and assessment.

Assessing effectiveness of conservation practices within the Little River watershed. One of the benefits of long-term data collection relates to the potential for subsequent integrative and comprehensive analyses. ARS scientists have collected stream flow and water quality data on the Little River Experimental Watershed (LREW) in South-Central GA for the past 37 years, and sediment and agrichemical concentrations in stream flow for the past 20 years. The resulting database contains hydrologic and water quality data, combined with terrain, soils, geology, vegetation, and conservation practices, for this watershed. The database was published in six manuscripts and via a public ftp site, and is being used to closely examine long-term water quantity and quality patterns for the watershed. The research illustrates the dramatic importance of riparian buffers within the watershed, which remove sediment and nutrients from upland agricultural sources, preventing them from entering adjacent streams and causing eutrophication.

Water quality modeling for large-scale watersheds. Agricultural pollutants in drainage waters have the potential to degrade the quality of waters used for municipal water supplies. ARS scientists in West Lafayette, IN, successfully calibrated and validated SWAT for modeling stream flow and atrazine concentrations in the Cedar Creek Watershed (CCW). This research is necessary for further use of SWAT as an assessment tool to evaluate the long-term effects of different management practices on chemical transport in large, tile-drained agricultural watersheds in the Midwest. The results are significant in that Cedar Creek is the main tributary to the St. Joseph River, the source of water supply for Ft. Wayne, IN, where concentrations of atrazine and other agricultural pollutants have been a major concern.

Problem Area 2—Irrigation Water Management

Plants for saline water reuse. High salinity levels prohibit the reuse of irrigation drainage waters from agricultural fields in the western US. ARS researchers at Parlier, CA, identified plant species and poplar tree clones adapted to these high salinity waters. As an example, oil plants adapted to high salinity drainage waters can be used for bio-based products that have economic value for the grower (e.g., biofuel and Se-enriched feed products). These findings improve our ability to sustain an agronomic-based system for drainage water reuse and encourage widespread use of degraded water for non-human consumptive uses, reducing competition for high quality water in the western U.S.

Salt Management Guide helps growers select horticultural crops that thrive in recycled waters. To assist landscape professionals, growers, and home gardeners in managing salinity in recycled irrigation waters, ARS scientists at the US Salinity Laboratory, Riverside, CA, in collaboration with researchers at the University of California Davis, developed a **Salt Management Guide**. The Guide and accompanying CD include an extensive list of plant species suitable for water reuse systems, ranging from relatively non-saline settings to salt-affected problem sites. The product provides: 1) information on public health aspects, and regulations on use, of Title 22 waters, and their suitability for landscape irrigation relative to plants, soil properties, and irrigation application systems; and 2) information to educate the public about safe use of recycled water and its value in helping to address current and future shortfalls in potable waters.

Enhanced nitrogen use efficiency in potato production. Better management of nitrogen fertilizer applications provide economic benefits to farmers and improve water quality. ARS scientists at Kimberly, ID, developed an alternative potato production system using 12-foot wide beds with five or seven rows across each bed. This alternate production system increases N use efficiency, increasing gross returns up to $300 per acre over conventional potato production in hilled rows. Western Ag Research, Blackfoot, ID, received a Conservation Innovation Grant in 2007 to demonstrate and evaluate this technology on 10,000 acres in southern ID.

Sustainability of Drainage Water Reuse Evaluated. Maintaining adequate supplies of freshwater to meet Earth's human and natural resource needs may be the most important natural resource challenge of the 21st Century. Drainage water reuse offers one means of increasing the availability of freshwater to support irrigated agriculture, while concomitantly reducing the volume of impaired drainage waters. ARS scientists at the U.S. Salinity Laboratory, Riverside, CA, evaluated the sustainability of drainage water reuse over a 5 year period (1999-2004), on a saline-sodic site on the west side of the San Joaquin Valley (WSJV). The evaluation demonstrated the reclamation of marginally productive WSJV saline-sodic soils, while reducing drainage volumes and serving as an alternative water resource for salt tolerant forage. At this site, rainage water reuse reduced salinity, Mo, B, and SAR from 1999-2004, with associated increases in forage yield and quality. The work confirms the short-term viability of drainage water reuse as an alternative water source for marginally productive WSJV saline-sodic soils, and as a means of reducing drainage volumes, thereby reducing the need for evaporation ponds. The unexpected appearance of low levels of Se, and the reappearance of Mo, at shallow soil depths suggest that long-term sustainability requires further investigation.

Water quality in a drainage water disposal facility. Due to elevated concentrations of toxic elements such as selenium and arsenic, drainage water disposal continues to be an environmental concern. ARS scientists in Parlier, CA examined the salinity, chemical characteristics, and biogeochemistry of selenium and arsenic in drainage waters from agricultural fields, and in an evaporation basin facility used for the disposal of agricultural drainage in the Tulare Lake Drainage District. Water parameters, including redox, dissolved oxygen, dissolved Fe and sulfur species, and speciation of selenium and arsenic, were determined in water columns as well as spatially in evaporation basins. This information is needed to evaluate the potential environmental impacts of agricultural production systems where drainage disposal is required.

Problem Area 3—Drainage Water Management Systems

A prototype nitrogen management tool for tile drained agriculture. Nitrogen losses from tile-drained agricultural systems in the upper Mississippi River watershed have been identified as a major factor contributing to the annual development of the hypoxic zone in the Gulf of Mexico. ARS researchers at Ames, IA, and Tucson, AZ, collaborated to develop a prototype spreadsheet tool capable of estimating N lost to surface waters from tile-drained agriculture. The tool uses statistical relationships from values measured in field experiments combined with a simulation model, providing a simple way to calculate the expected reduction in N loading from potential management changes. The prototype has the potential to become an operational N management tool for use by farmers, growers, and natural resource managers, that will help maintain the sustainability of US agricultural practices while enhancing the environment.

Relative Impacts of Ionic Strength and Nitrate Concentration on Nitrate Movement in Soil. Nitrate is a widespread contaminant found in both ground and surface waters. Nitrate in the environment typically moves through the soil profile first, especially if introduced via fertilizer application. Reducing adverse environmental impacts due to nitrate requires a better understanding of the processes that govern nitrate mobility in soil, particularly anion exclusion. In a laboratory investigation, ARS scientists in Columbus, OH, found that the ionic strength of the soil solution had a much greater influence on the anion exclusion process affecting nitrate mobility than the nitrate concentration itself. The results of this study will help improve computer models used to predict nitrate movement through the soil profile, leading to improved management of nitrate fertilizer application scenarios, reducing nitrate losses from fertilized agricultural fields. A manuscript describing these findings has been accepted for publication in the scientific journal, Soil Science.

Management Effects on Nitrogen in Tile Drained Agriculture. Nitrogen losses from agricultural lands in the Mississippi River Basin contribute significantly to the annual development of the hypoxic zone in the Gulf of Mexico. ARS scientists at the National Soil Tilth Laboratory in Ames, IA, in collaboration with scientists from ARS' Agricultural Systems Research Unit in Fort Collins, CO, summarized and quantified the effects of management on nitrogen (N) losses to surface waters, based on a rich dataset of observations and an improved, process-based simulation model (RZWQM), through a series of papers published as a special issue of Geoderma. Both water and N losses from tile drained agricultural systems in the Midwest are addressed, as influenced by a variety of management practices. This special issue will be a key resource for future efforts to control the magnitude and extent of the hypoxic zone in the Gulf of Mexico, by reducing N loadings from tile-drained agriculture in the Mississippi River Basin.

Farmers Can Save Money and Help the Environment. Nitrogen losses from agricultural lands can be reduced more readily if farmers benefit through increased revenues. ARS scientists at the Southwest Watershed Research Center, Tucson, AZ, used NRCS' EconDocs software to develop a series of crop budgets for current and reduced N loading management systems in tile-drained agriculture. These budgets demonstrate to farmers the economic benefits of management systems that reduce N loadings, and could be used to revise conservation programs to encourage farmers to adopt management systems that reduce N loadings from tile-drained agricultural systems.

RZWQM Model Evaluation of Cropping System Management Practices. Nitrogen losses from agricultural lands represent a serious water quality problem in many areas of the US, including the Mississippi River Basin and the Chesapeake Bay. Winter cover crops (e.g., winter rye in corn-soybean rotation) are one of the more promising practices to reduce nitrate losses without negatively affecting production. ARS scientists in Fort Collins, CO, calibrated the hybrid RZWQM-DSSAT model, and tested its ability to simulate the effects of cover crops versus no cover crops on nitrate leaching losses in subsurface drainage water under a corn-soybean rotation. Field data from Boone County, IA, collected over several years under an application rate of 225 kg N ha-1 in corn years, were used for model evaluation. Average observed and RZWQM simulated flow-weighted annual nitrate concentrations (FWANC) in subsurface drainage waters for the cover crop treatments from 2002 to 2005 were 8.7 and 8.6 mg L-1, compared to 22.1 and 17.2 mg L-1 for no cover crop (resulting in observed and predicted reductions of 61% and 50%, respectively). Simulations based on various N fertilizer application rates showed that annual FWANC in subsurface drainage water dramatically increased with increases in N application rate. With a cover crop, average FWANC increased from 3.1 mg L-1 at the 0 kg N ha-1 rate to 13.1 mg L-1 at 250 kg N ha-1 rate. In comparison, a corresponding increase, from 6.1 mg L-1 to 21.1 mg L-1, was observed without a cover crop present. Accurate quantification of the nutrient removal potential of various cover crops could be linked to nutrient credit trading scenarios, to foster the adoption of conservation practices aimed at improving water quality.

Problem Area 4—Integrated Soil Erosion and Sedimentation Technologies

Starch/Polyacrylamide Soil Erosion Amendment. Water flowing in irrigation furrows can erode soil and transport sediment and associated nutrients off the field. A new polysaccharide/polyacrylamide amendment was compared against polyacrylamide-treated and untreated furrows in a field test at the Northwest Irrigation and Soils Research Laboratory, Kimberly, ID. The new amendment, a blend of potato starch and polyacrylamide (PAM), increased infiltration by 20%, and reduced soil erosion by 65%, compared to untreated furrows. PAM treatment increased infiltration by 13%, and reduced erosion 98%, compared to untreated furrows. The new polysaccharide/PAM amendment provides an alternative to PAM for improving infiltration on furrow irrigated fields, although greater application rates will be needed to provide similar erosion control as PAM.

Prototype model simulates erosion and sediment deposition patterns due to soil translocation by tillage. Accurate quantification of erosion is an important component of developing tillage practices that minimize soil and associated nutrient losses from agricultural fields. ARS scientists at Oxford, MS, computed the amount of soil translocated following tillage, by taking into account slope gradients parallel and perpendicular to the direction of tillage. The prototype model operates on a rectangular grid represented by a Digital Elevation Map (DEM) containing initial terrain elevations. The model, which has been programmed in Fortran 90 using Compaq's Visual FORTRAN 6.6 compiler for Windows, should provide a valuable future tool for quantifying the effects of agricultural practices on soil erosion and sedimentation at the landscape scale.

A physically-based integrated numerical model for flow, sediment, and contaminant transport in the surface-subsurface system. Models are useful tools for estimating processes at scales larger than can be readily measured through empirical analyses. ARS scientists at Oxford, MS, developed a numerical model to estimate flow, sediment, and contaminant transport in surface-subsurface systems, by combining separate models for surface and subsurface environments. Surface flow is calculated using a depth-averaged 2-D diffusion wave model; ground water flow is computed using the 3-D mixed-form Richards equation. Coupling of these two component models allows assessment of interactions between surface and groundwater flows, which are difficult to measure directly, particularly at the landscape scale.

Sediment yields from cotton drastically reduced. Erosion and associated soil loss are common problems associated with cotton cultivation in the southern US, particularly on sloping terrain. Standard approaches for growing cotton on sloping lands produce rates of erosion and sediment yield several times greater than the 7t/ha tolerance value. ARS scientists at Oxford, MS, conducted a four-year study that included measuring water runoff and sediment yield from plots cultivated for cotton with conventional approaches, and from plots representing three innovative approaches involving combinations of narrow row spacing, no-till, and grass hedges. Sediment yield from no-till plots with grass hedges was reduced 94% relative to conventional tillage, and yielded an average of 0.2 t/ha of cotton more than conventional tilled plots. Results will be useful in guiding future research on field-sized areas, with potential benefits for extension personnel, action agencies involved in water quality planning, and farmers.

Index for targeting pollution hotspots. Often only a relatively small area is responsible for a disproportionate fraction of the fine sediment and associated chemical load leaving a watershed. If these 'hotspots' can be identified, conservation practices can be targeted to specific locations within a watershed where they will provide maximum benefit, reducing the cost of conservation management in comparison with implementing practices throughout a watershed. In this study, ARS scientists developed a sediment production index using data from the Walnut Gulch Experimental Watershed at Tombstone, AZ, that showed that the greatest potential for sediment production was on south facing slopes with a steepness of between 13% and 20%. The ability to identify primary sediment source areas in watersheds should improve the design of best management practices while reducing the cost of their implementation.

Problem Area 5—Watershed Management, Water Availability, and Ecosystem Restoration

New tool for assessing of root zone contaminants. Land application of biosolids can introduce persistent, slow moving trace metals and other contaminants to the subsurface environment, affecting environmental quality and human health for decades; safe use of biosolids in agriculture requires accurate risk assessment of contaminant fate and transport. Researchers at the U.S. Salinity Laboratory, in collaboration with scientists in Sweden and Brazil, developed a new contaminant transport model suitable for assessing the transport of slow moving contaminants in the root zone. The model has relatively modest data requirements, yet is more realistic than other root-zone models currently in use or proposed for use in biosolid risk assessment. This new modeling tool will benefit both researchers and regulators who are charged with assessing the impacts of persistent contaminants in the root zone.

Stream restoration that works. Over $1 billion are expended annually on stream restoration, but few projects are monitored following restoration, and scientists disagree about the most effective approaches to achieve various restoration objectives. ARS scientists in Oxford, MS, monitored streams for ten years after the surrounding watersheds were treated with standard erosion control practices. In addition, two stream reaches were treated with special features to restore fish habitat quality. Habitat restoration produced major shifts in the types and sizes of fish present—shifts that did not occur in non-treated stream sections. The study demonstrates that even watershed-scale application of traditional erosion control measures is not adequate to restore stream ecological integrity, while identifying effective approaches to specifically address fish habitat deficiencies. This research will be beneficial to managers charged with both controlling erosion and restoring fish habitat and ecological integrity in streams draining agricultural watersheds.

Rotating crops encourages atrazine degradation. Under ideal conditions, pesticides applied to agricultural crops would rapidly degrade after application, but factors that promote such ideal behavior are largely unknown. Commonly, some portion of the applied pesticide often ends up in associated aquatic ecosystems. ARS scientists in Oxford, MS, compared bacterial populations and carbon and nitrogen levels in soils supporting continuous cotton cultivation, continuous corn, and a corn-cotton rotation. Continuous corn and a corn-cotton rotation favored the accelerated degradation of atrazine, a widely used herbicide, as compared to continuous cotton cultivation. This discovery has prompted new studies to ascertain the effect of accelerated atrazine degradation on weed control potential. However, the results indicate that replacing continuous cotton cultivation with a corn-cotton rotation has the potential to reduce pesticide transport to associated aquatic environments.

Pesticides may leave sediments and harm animals. Agricultural pesticides are often removed from streams, lakes and wetlands by becoming attached to sediments and settling to the bottom, but the subsequent fate of these pesticides is often unknown. By mixing sediment sampled from a wide range of aquatic environments adjacent to cultivated fields with water and then exposing aquatic insects to this mixture for 28 days, it was shown that compounds moved from the sediments into the animals' tissues. These findings will guide future studies of the movements and fate of such liberated pesticides in aquatic ecosystems.

Properly managed forage-based livestock operations do not appear to contribute to poor water quality. Forage-based livestock systems have been implicated as major contributors to deteriorating water quality in many parts of the US. Both fertilizers and manures represent sources of phosphorus that can be transported via hydrologic pathways, impacting surface and ground water quality. Scientists at the USDA/ARS Subtropical Agricultural Research Station in Brooksville, FL, examined historical water quality parameters in three lakes located near beef cattle pastures: 1) Lake Lindsey; 2) Spring Lake; and 3) Bystre Lake. Based upon the Florida Water Quality Standard, water quality in all three lakes was considered "good" (30-46 TSI). In Lake Lindsey, measures of water chemistry from the 1990s were similar to those from the 1960s. Spring Lake contained clear (color < 10 units), medium hard water with low concentrations of total N and total P. Bystre Lake was characterized by moderately colored, medium hard waters. Findings suggest that properly managed beef cattle operations might not be major contributors to excessive nutrient loads (especially of P) in surface waters. Current fertilization recommendations for forage-based pastures in central Florida appear to offer little potential for negatively impacting water quality, while properly managed livestock operations appear to contribute negligible loads of nutrients (especially P) to surface water. Periodic application of additional P and other micronutrients may be necessary to sustain agronomic needs and to offset the export of nutrients due to animal production. Knowledge gained through this study can be used to inform the management of forage-based livestock systems in humid temperate and sub-tropical environments on similar soils.

Enhancing water quality from horticultural production. Over the past ten years, the area planted in field crops and orchards in South Florida has decreased dramatically, while the area in floricultural crops has steadily increased. As a result, ARS scientists in Miami, FL, have begun to develop BMPs that reduce or mitigate nutrient leaching from horticultural and floricultural production systems, to enhance water quality in South Florida. Scientists are specifically working to: 1) develop inexpensive, readily available potting substrates from waste generated by commercial nurseries and debris from construction sites; and 2) identify plants of commercial value that can serve as biological accumulators of excess nutrients and metals generated during nursery operations, for use in border strips to reduce the movement of hazardous materials offsite to adjacent riparian areas. When fully developed, this technology will benefit customers in the nursery industry, the fertilizer industry, and other commodity associations, by providing guidance on management practices that reduce the potential movement of nutrients offsite, and by developing growth media that utilize locally generated solid waste to enhance production efficiency while simultaneously ameliorating the negative impacts of solid waste collection sites.

Problem Area 6—Water Quality Protection Systems

Developing sensors and procedures for corn N management. A significant proportion of the nitrogen losses from agricultural lands are associated with nitrogen fertilizers added in excess of crop nitrogen requirements. ARS scientists in Lincoln, NE, finalized the development of the Crop Circle active sensor system for N management through a CRADA with Holland Scientific (Lincoln, NE), and developed procedures for its effective use. Sensor readings provided rapid, accurate assessments of plant canopy greenness. Use of this sensor system to guide variable rate N applications has the potential to improve N use efficiency, enhancing both the environmental and economic quality of corn production, while reducing nitrogen losses from agricultural fields that contribute to the eutrophication of aquatic ecosystems.

Vegetative buffers help reduce nutrients in soil and groundwater. Vegetative buffers are often used to reduce pollutant exports in waters draining from agricultural fields. Effective vegetative buffers require grass species that can capture nutrients before they run off the surface or leach to groundwater. ARS scientists at Columbia, MO, in collaboration with scientists at the University of Missouri, conducted a field study using five grass treatments (orchardgrass, tall fescue, smooth bromegrass, timothy, and switchgrass) compared to a bare ground control, to evaluate the ability of the grasses to remove nutrients, preventing their transport to shallow groundwater. All grass species except timothy reduced nitrate concentrations in shallow groundwater by ~99% compared to the control; switchgrass also reduced phosphate leaching by 60 to 74%. Grass treatments reduced soil nitrate levels by 41 to 91%. Overall, switchgrass, smooth bromegrass, and tall fescue were the most suitable for use in vegetative buffers because of their superior ability to reduce soil nitrate and nutrient leaching. These findings provide important information to improve the design of vegetative buffers, increasing their effectiveness in nutrient removal.

Refining constructed wetland technologies for treating agricultural runoff. Degradation of water quality due to agricultural pollution is of global concern. Some treatment strategies use constructed, natural, or restored wetlands as buffers between agricultural fields and nearby water sources. ARS scientists at Oxford, MS, found that the long-term growth patterns of live, caged mussels placed in a constructed wetland were affected by insecticide received in artificial runoff, and documented elevated releases of phosphorus during winter die off when a common wetland plant species was exposed to elevated levels of nitrogen and phosphorus. These findings will help refine technologies that use wetlands to ameliorate agricultural pollution, allowing more informed decisions regarding nutrient and insecticide best management practices.

Matrix Based Fertilizer Formulations Reduce N and P Losses By More Than 60%. Loss of soluble nitrogen (N) and phosphorus (P) from fertilizers to surface and ground water is an unfortunate side effect of agricultural, turf, nursery and home fertilizer use. A new fertilizer formulation strategy was developed at the Northwest Irrigation and Soil Research Laboratory, Kimberly, ID, that employs chemical fixation and ion exchange, rather than encapsulation, to slow the release of N and P. In greenhouse studies, these formulations, which are patent pending, reduced N and P leaching losses by over 60%. More than thirty industry enquiries for joint development and licensing to date attest to the potential for commercial development of matrix based fertilizer formulations to help reduce nutrient losses from fertilizer applications.

Reaction of Chlorine and Isoxaflutole (Balance). Herbicides present in untreated water can react with the chlorine used by water treatment plants for disinfection. ARS scientists with the Cropping Systems and Water Quality Research Unit, Columbia, MO, in collaboration with the University of Missouri, studied the breakdown of DKN, the herbicidal metabolite of the corn herbicide isoxaflutole (Balance), by chlorine. DKN has been shown to be both present in the surface waters of the major corn-growing states, and to rapidly react with chlorine. Results showed that DKN was completely broken down by chlorine during the water treatment process, but that two potentially harmful products were formed: cyclopropanecarboxylic acid (CPCA) and dichloroacetonitrile (DCAN). Fortunately, levels of CPCA and DCAN formed were below those reported to cause toxic effects in humans or animals. This research identifies a potential human health issue associated with agricultural production, demonstrating the chlorination results in the complete breakdown of DKN, generating potentially harmful breakdown products (CPCA and DCAN) that appear to be present only at sub-toxic levels in resulting drinking water supplies. Best management practices might suggest routine CPCA and DCAN monitoring of chlorinated drinking water, and the development of techniques to remove these products from drinking water supplies.

New Analytical Methods Aid In Identifying Herbicides and Their Metabolites in Soils and Plants. Accurately assessing the fate of herbicides and their metabolites in the environment requires the development of sensitive analytical techniques. ARS and University of Missouri scientists collaborated to develop two new analytical methods: one for the analysis of atrazine and its chlorinated metabolites in plants, and the other for the analysis of isoxaflutole (IXF) and its two primary metabolites in soils and plants. Both methods employ chromatography to separate the compounds of interest. Subsequent detection by mass spectrometry results in sub-part per billion detection limits (1 to 2 orders of magnitude more sensitive than previously published methods). To demonstrate their utility, these methods were applied to measurements of plants or soils from a field experiment. Results showed that in forage grasses, the ratio of metabolites to parent compound were good indicators of the detoxification pathways and overall sensitivity to each herbicide. Scientists, regulators, and industry will benefit from the availability of these appropriately sensitive methods for measuring herbicides and their metabolites in the environment, facilitating an improved understanding of their fate in the environmental fate, and leading to the implementation of vegetative buffers that more effectively prevent contamination of surface and ground waters.

Pollutants in agricultural drainage waters can negatively affect organisms inhabiting wetlands constructed for water quality improvement. Constructed wetlands can be used as buffers between agricultural fields and nearby water sources, but the pollutants carried in runoff can harm organisms living in the treatment wetland. Live, caged mussels were placed in a constructed wetland receiving insecticide in an artificial runoff event. Although all of the mussels survived the event, long-term growth effects were observed. These findings will be used to refine the design of wetland construction projects for treating agricultural runoff.

Summer cover crops reduce atrazine leaching to shallow groundwater in southern Florida. South Florida's surficial aquifer provides potable water for nearly all of South Florida's rapidly growing population. Agricultural practices, which contribute to water quality impairment, have the potential to adversely affect the massive project focused on restoring south Florida's Everglades ecosystem. Investigations were conducted in southern Florida to assess risks to groundwater quality from atrazine, used for sweet corn production in the region, and whether maintaining fields with a highly vigorous cover crop, Sun Hemp [Crotalaria juncea L.], during summer fallow periods would reduce impacts. Results demonstrated that climatic and cropping patterns, and relatively high dilution rates in the surficial aquifer, combined with high atrazine degradation rates in soil to limit contamination levels compared to other atrazine use sites. Measurements also showed that cover crop use leads to significantly lower contaminant levels in groundwater. Atrazine use presents a small, although potential significant, risk to groundwater quality in southern Florida, and that the use of a cover crop like Sun Hemp during summer months, when fields are fallow, may be an effective mitigation measure. As a result of this research, growers are being strongly encouraged to plant cover crops, which have many other potential benefits (e.g., reduced nutrient leaching and wind erosion; improved soil quality) in addition to reducing herbicide leaching.