FY2010 Annual Report
National Program 212 – Climate Change, Soils, and Air Emissions

Introduction

National Program (NP) 212 Climate Change, Soils and Air Emissions supports research to improve the quality of atmosphere and soil resources that both affect and are affected by agriculture, to understand the effects of climate change on agriculture, and to prepare agriculture for adaptation to climate change.

Agricultural systems function within the soil-atmosphere continuum. Mass and energy exchange processes occur within this continuum and agriculture can significantly affect the processes. Emissions from agriculture to the atmosphere affect air quality and increase atmospheric greenhouse gas (GHG) concentrations. While GHG emissions are a part of the natural cycling of carbon (C) and nitrogen (N), these emissions also contribute to climate change. A changing climate impacts agriculture, range and pasture systems, and soils through alterations of precipitation and temperature patterns, and increased atmospheric carbon dioxide (CO_2) concentration. The impacts of climate change create challenges to agriculture and ecosystem services, but also offer new opportunities for agricultural production and enhancement of soil quality.

Soils are a crucial boundary resource between agriculture and the atmosphere. Soils in agricultural systems must be managed to meet rising global demands for food, feed, fiber, fuel and ecosystem services while maintaining soil productivity and limiting undesirable interactions between soils and the atmosphere. Soil degradation through erosion and decreased physical (e.g., structure, compaction, infiltration), chemical (e.g., acidification, salinization, nutrient depletion), and biological (e.g., biodiversity, nutrient cycling, soil organic matter) properties and processes must be mitigated to ensure critical goods and services provided by soil resources are maintained. New approaches to managing and improving soil resources coupled with the significant strides being made to develop new varieties of crops via genomics, offer great potential for meeting these rising global demands.

The variability of the atmosphere, soils, and plants, and the complexity of interactions among these systems require collaborations by ARS scientists conducting NP212 research. Formal and informal Cross Location Research (CLR) projects including the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), the Renewable Energy Assessment Project (REAP), and field campaigns focused on air quality are successful examples. Synthesis and integration of information, including sources outside NP212, by CLR projects increases the utility and impact of ARS research. Efficient assimilation of data from NP212 projects into existing and future collaborative databases will enhance synthesis and integration analyses and expand research opportunities.

Research reports are organized according to the Research Components of the NP212 Action Plan:

1. Enable Improvements of Air Quality via Management and Mitigation of Emissions from Agricultural Operations
2. Develop Knowledge and Technologies for Reducing Atmospheric Greenhouse Gas Concentrations Through Management of Agricultural Emissions and Carbon Sequestration
3. Enable Agriculture to Adapt to Climate Change
4. Maintaining and Enhancing Soil Resources

Research under the first component was formerly conducted and reported under NP203 Air Quality. The second component is focused on mitigation of climate change while the third component is focused on adaptation to climate change. Research on climate change was formerly conducted and reported under NP204 Global Change. The fourth component encompasses research that was formerly conducted under NP202 Soil Resource Management. All of the research conducted under NP 212 Climate Change, Soils and Air Emissions, uses the approaches of:

- Understanding and measuring the important factors,
- Modeling or enabling prediction of process outcomes using measureable factors as inputs,
- Enabling management of factors and conditions affecting processes to achieve desired solutions or improvements.

Working groups of ARS scientists from different geographic locations and ARS National Programs contribute to the objectives of climate change, air quality and soils research.

The November/December 2009 Agricultural Research Magazine was a special issue devoted largely to climate change. This issue contains eight articles that provide a good representative sample of the types of climate change research that ARS conducts. An electronic version of this issue can be downloaded from http://www.ars.usda.gov/is/AR/archive/nov09/.

Component 1: Enable Improvements of Air Quality via Management and Mitigation of Emissions from Agricultural Operations

Atmospheric emissions from agriculture are under increased scrutiny due to potential negative environmental effects and threats to human and animal welfare. Emissions contribute to tensions between agriculture and residential communities from visibility impairment (haze) and nuisance odors. Major classes of emissions include particulate matter (PM), volatile inorganic compounds (primarily ammonia and hydrogen sulfide), volatile organic compounds (VOCs), and those from pesticides. Often these emissions exist as mixtures and, thus, adjustments to production practices for abatement may decrease the release of one material while changing the emission character or magnitude of other materials.

An ARS Air Quality Researchers Working Group has been formed to better coordinate agricultural air quality research activities, stewardship of research data, and delivery of information and research products to producers and policy-makers. Information exchange and collaboration is currently underway with USDA- Natural Resources Conservation Service

(NRCS), University researchers, EPA, NOAA, and NASA. The ARS Air Quality research community also regularly communicates with the Agricultural Air Quality Task Force convened by NRCS.

Selected Accomplishments: Air Quality Research

Simplified method for determining the susceptibility of soils to wind erosion. The wind erodible fraction (WEF) is a measure of the susceptibility of soils to erosion by wind and provides a useful tool for planning farming production strategies. The standard method for measuring WEF uses a laboratory-based rotary sieve that requires transportation of soil samples to the laboratory. Unfortunately, soils tend to break up during transport to the laboratory, yielding erroneous results. A rapid and simple field-based sieving protocol for determining WEF was developed by ARS researchers in Manhattan, KS. The protocol was described in a report delivered to NRCS and is now being used by NRCS in the field on a limited test-basis as a quick method for determining temporal WEF. This method is also being incorporated into the NRCS National Agronomy Manual of policy and procedures for wind erosion. NRCS is now better-equipped to help landowners increase air quality and improve soil sustainability via reductions of wind-eroded soil.

New method to "fingerprint" particulate matter emitted from cattle feedlots. Current methods to evaluate particle concentrations from cattle feedlots fail to identify the sources, thus limiting progress towards strategies to reduce particulate emissions. Using Raman microscopy methods, ARS scientists from Beltsville, MD examined the chemical profile of individual particles captured downwind from a cattle feedlot and compared them with the chemical profiles of particles taken from potential sources within the feedlot. Positive matches enabled sourcing of airborne samples to a specific location within the field lot. This approach can be used to determine the most important sources of particles to the total particle emission flux. Detailed information on particle sources will be useful for evaluating the efficacy of existing and future improved dust management practices.

New model for estimating ammonia emissions from dairy manure. There is a need to update tools for predicting ammonia emissions from dairy livestock manure, as existing models are based upon old data from obsolete dairy facilities. ARS scientists at University Park, PA collected data from a range of modern dairy facilities and developed new equations that were found to better estimate ammonia emissions from dairies currently being operated. The new findings are being integrated into a decision support tool that will enable producers to evaluate the effects of nitrogen management and thus ammonia mitigation strategies, on the total air emissions from farms. Use of the updated decision support tool enables increased nitrogen use efficiency, which in turn reduces ammonia emissions and can increase profit margins. Reducing ammonia emissions improves both air, and water quality via reduced deposition of atmospheric nitrogen.

Rapid assay for prediction of residue decomposition. Wheat and barley cultivars that do not rapidly decompose have hindered the implementation of conservation farming systems and reduced-till and no-till seeding in the dryland Pacific Northwest. These practices, once implemented, can reduce soil erosion, which degrades air quality. Additional knowledge on cereal straw decomposition is needed to help growers design crop rotations that promote the adaptation of reduced-till and no-till seeding. ARS scientists in Pullman, WA, in collaboration with Washington State University scientists, have developed a quick method using near-infrared technology to identify the fiber and nutrient composition of spring wheat, winter wheat and spring barley straw, and predict straw decomposition in different cultivars. Information on differences in straw decomposition among wheat and barley cultivars will help growers select cultivars for reduced tillage systems.

Component 2: Develop Knowledge and Technologies for Reducing Atmospheric Greenhouse Gas Concentrations through Management of Agricultural Emissions and Carbon Sequestration

Agricultural GHG emissions to the atmosphere are among the documented anthropogenic factors driving climate change. Of critical importance to GHG reductions and improved efficiency of fertilizer management is the reduction of nitrous oxide (N_2O), as agriculture is the largest anthropogenic source of this GHG. Land management practices may be altered to reduce GHG emissions. Agriculture also provides an opportunity to sequester C in soils, thus offsetting GHG emissions and offering a partial solution to slowing the forces of climate change.

ARS has made significant contributions to the recently-released USDA Climate Change Science Plan (available from: http://www.usda.gov/oce/climate_change/science_plan2010/USDA_CCSPlan_112910.pdf), and to USDA efforts to develop programs promoting carbon sequestration and GHG emission reductions. The nationwide ARS Greenhouse gas Reductions through Agricultural Carbon Enhancement network project (GRACEnet: http://www.ars.usda.gov/research/programs/programs.htm?np_code=212&docid=21223) continues to provide critically-needed information to enable agriculture to reduce its impact on climate via GHG emission reductions, and to reduce atmospheric greenhouse gas concentrations through soil carbon enhancement.

ARS also supports the U.S. role in the Global Research Alliance on Agricultural Greenhouse Gases (“GRA”), an international effort to reduce agricultural greenhouse gas emissions that was endorsed by Agriculture Secretary Vilsack during the Copenhagen climate change meetings in December, 2009. ARS scientists provide the international coordination for the GRA Croplands Research Group, represent the U.S. in the GRA Paddy Rice Research Group and have contributed to the US contributions to the GRA Livestock Research Group.

Selected Accomplishments: Climate Change Mitigation Research

Influence of nitrogen fertilizer forms on greenhouse gas emissions from corn depends on production and environmental conditions. A significant source of nitrous oxide (N_2O), a greenhouse gas with significantly greater impact on climate change than carbon dioxide emissions, is from the use of nitrogen (N) fertilizers. Use of enhanced-efficiency N fertilizers (controlled release and stabilized nitrogen sources) was shown to influence the amount of N_2O emitted from irrigated no-till corn. In no-till irrigated corn in the semiarid western U.S., nitrous oxide emissions monitored by ARS scientists in Fort Collins, CO during the 2007 and 2008 growing seasons were reduced up to 53% by the use of enhanced-efficiency N fertilizers when compared to dry granular urea, and up to 35% when compared to liquid urea-ammonium nitrate fertilizers commonly used by farmers. In another study, ARS researchers in Ames, IA tested the use of stabilized nitrogen fertilizer as a means of reducing nitrous oxide (N_2O) greenhouse gas emissions from a non-irrigated corn crop; in that case, N_2O emissions were not reduced, but crop yield was increased. In the Iowa experiment, the stabilized materials appeared to affect the nitrate and ammonium pools in the soil through a reduction of ammonia volatilization when the materials are applied; the increase in crop yield reflected an increase in nitrogen availability during the grain-filling period as these plants showed a greater amount of leaf greenness, larger grain size and ultimately larger crop yield. Thus, for temperate climates, the soil water balance is a dominant factor affecting N_2O emissions, and that changing forms of nitrogen to include stabilized materials could have a yield advantage but not necessarily a greenhouse gas emission advantage. Together, the two studies provide important early steps towards regional-specific guidelines for reduction of greenhouse gases from agricultural sources, while maintaining or increasing crop yields.

An improved remote sensing method for assessing crop residue cover. Crop residue cover, a product of low-till and no-till farming, is an important tool for controlling soil erosion, enhancing soil productivity and increasing soil carbon sequestration. Current methods of measuring residue cover for management decisions are inadequate for characterizing the spatial variability of residue cover over many fields. Measurements based on Landsat satellite data for mapping residue cover are often confounded by changes in how the soil itself reflects light. There are reliable ways to get the data based on very narrow ranges of reflected wavelengths, but that kind of imagery is expensive and not widely available. An alternative approach was proposed and tested at five locations in the U.S. on multiple dates. Results show that a minimal upgrade from one broad Landsat wavelength band to two or three relatively narrow bands would provide reliable estimates of crop residue cover and soil tillage intensity data for regional assessments of conservation practices. This work advances crop residue mapping, as well as biogeochemical models that produce credible estimates of soil carbon at watershed and regional scales.

Methods for rapid measurement of soil organic carbon (SOC) and SOC pools assessed. A quick, reliable method to measure SOC is required for assessing large numbers of soil samples needed to characterize the SOC of whole fields and landscapes. The data is needed for management decisions, verification of C states for environmental credit trading, and validation of C models. The methods tested for rapid measurement of SOC included use of near- and mid-infrared measurements and pyrolysis molecular beam mass spectrometric (pyMBMS) analyses. ARS scientists from Fort Collins, CO, used methods that were calibrated and/or compared to traditional laboratory methods to measure the total SOC, microbial biomass C, particulate organic matter C, mineral associated C, soil inorganic C (SIC). The results of these studies show that mid-infrared methods were superior to near-infrared methods for measuring total SOC and microbial biomass C. The mid-infrared method had the advantage of being more sensitive for some measures, while the pyMBMS method allowed an evaluation of the organic molecules that were associated with various SOC pools, thus possibly helping to identify pathways for C cycling and sequestration. These findings provide a step towards the development of rapid and potentially mobile methods of reliably assessing the effectiveness of soil carbon management.

Soil conditioning index (SCI) calibrated to soil organic carbon for Southeastern U.S. Rapid and reliable assessments of the potential for agricultural management systems to sequester SOC are needed to promote conservation and mitigate GHG emissions. A collaborative effort to investigate the validity of the soil conditioning index for prediction of soil organic carbon sequestration was developed among scientists with ARS in Watkinsville, GA, a former ARS research associate in Beltsville, MD (now at the National University in Asuncion, Paraguay), and with Natural Resource Conservation Service (NRCS) in Temple, TX. Published measurement of SOC from various studies throughout the southeastern U.S. were compared with computer simulations of SOC based on the soil conditioning index and the Revised Universal Soil Loss Equation. Within a field study, the soil conditioning index was usually highly related to SOC content. Across studies, SOC would increase by 0.25 tons of carbon dioxide per acre per year per unit change in Soil Conditioning Index (SCI). These results will have important implications for farmers, crop advisors, scientists, and policy makers interested in carbon trading schemes throughout the 300 million acres of land in the southeastern U.S.

Component 3: Enable Agriculture to Adapt to Climate Change

Mechanisms for adapting to climate change are critical for continued agricultural production and stewardship of natural resources. An understanding of the impacts of climate change on natural and managed ecosystems provides insights needed to formulate strategies for addressing vulnerabilities and exploiting potentially beneficial aspects of climate change. Mechanisms for identifying and detecting indicators of impacts are key to formulating management responses. Adaptive responses to climate change must be evaluated for impacts on ecosystem function and potential feedbacks on the climate system and subsequent consequences for sustainability and reinforcement, or offset of, climate change mitigation strategies.

ARS conducts research under Natural Resources and Sustainable Agriculture Systems, Crop Production and Protection, Animal Production and Protection, and Nutrition, Food Safety/Quality that contributes to the resiliency of agriculture to the effects of changing climate. The accomplishments listed below focus on those from Natural Resources and Sustainable Agriculture Systems projects.

Selected Accomplishments: Climate Change Adaptation Research

Rising atmospheric CO_2 favors weedy rice over cultivated rice. Rising atmospheric CO_2 increases the growth of many crops and enhances the growth of many weeds. Weedy red rice is a troublesome weed in cultivated rice fields that reduces the quantity and quality of rice harvested for food. Research showed that weedy red rice growth increased more with additional CO_2 than cultivated rice. Further, higher CO_2 increased the ability of weedy red rice to compete with cultivated rice, to the detriment of rice yield. These results document greater susceptibility of rice production to in-field competition from greater weed vigor driven by rising atmospheric CO_2, and highlight the need to assess the combined impacts of increasing atmospheric CO_2 and rising air temperatures on global rice production.

Predicting plant invasions in an era of global change. Global change is expected to dramatically alter invasive plant occurrences and will require corresponding changes of land management. ARS scientists from Cheyenne, WY and Ft. Collins, CO, collaborated with two Princeton University scientists to provide a new framework for examining this issue in an invited review and synthesis article. Supported by findings from both modeling and experimental studies, the scientists concluded that global changes that increase the availability of plant resources, such as atmospheric CO_2 enrichment and N pollution, are most likely to cause plant invasion. They proposed management changes needed to combat invasive plants in the face of global change. This work will be used extensively, both by global change biology researchers to better understand climate change impacts on ecosystems, and by managers of natural and semi-natural ecosystems.

Effects of elevated CO_2 on crop yield evaluated. At least nine research groups from around the world have conducted FACE (free-air CO_2 enrichment) experiments on ten or more crops over the last two decades to determine how increasing concentration of atmospheric CO_2 will likely affect future crop yields. An ARS scientist from the U.S. Arid-Land Agricultural Research Center, Maricopa, AZ analyzed the collective results of these experiments and concluded that yields of sorghum, a C4 crop, were unaffected, whereas yields of C3 crops were increased 16 to 40 percent under atmospheric CO_2 concentrations of roughly 550 ppm. For example, yields of C3 grain crops (wheat, rice, barley, soybean) were increased roughly 17 percent on average. Results from the China FACE Rice Project showed 32 percent increases for some hybrid rice varieties. These results show that given minimal climatic change impacts of increasing temperature, changing water availability, etc., future C3, but not C4, crop yield will increase due to the effects of elevated atmospheric CO_2 on plants. Given detrimental impacts of increasing temperature, changing water availability, etc., these direct CO_2 effects will tend to mitigate the harm. The results are critically important for estimating future food production and offer insights for potential changes to agricultural systems needed to increase world food production.

Incidence of forest diseases decreased on plants exposed to elevated atmospheric carbon dioxide. Plant diseases cost growers billions of dollars each year in control and lost productivity. Understanding how the rising level of atmospheric carbon dioxide may alter incidence and severity of important plant diseases is crucial to future management strategies. ARS researchers in Auburn, AL determined that the incidence of both pitch canker and fusiform rust were lower on loblolly pines grown under elevated carbon dioxide; fusiform rust took longer to develop on red oak seedlings exposed to elevated carbon dioxide; and carbon dioxide did not affect disease severity. Data suggests that some plants may benefit from the rising level of carbon dioxide through decreased fungal disease incidence. This information provides insights to the susceptibility and resilience of plants to changing climatic conditions and can be used to plan for plant disease risk management planning.

Atmospheric CO_2 enrichment increases root biomass of a grassland ecosystem. Most organic carbon in grasslands resides in soil, having been derived from plant roots. This pool of C may increase and thereby slow the accumulation of CO_2 in air if increasing CO_2 stimulates root production without a compensating increase in the rate at which soil organisms decompose dead roots. ARS researchers at Temple, TX, together with collaborators from Duke University, measured root biomass in grassland communities exposed to a continuous gradient in atmospheric CO_2 spanning pre-Industrial conditions to elevated concentrations. Increasing CO_2 caused a significant increase in root biomass of plant communities, with linear or curvilinear responses to CO_2 depending on sampling date. Carbon dioxide enrichment reduced the lifespan of roots of the dominant perennial grass when neighboring roots were frequent, implying that CO_2-enriched plants readily shed or turnover roots located in zones of dense root growth. The results indicate that increasing CO_2 concentration may increase soil C storage in grassland ecosystems by stimulating root production and turnover. This information provides a useful selection criterion for the development of new grass varieties optimized for C sequestration.

Component 4: Maintaining and Enhancing Soil Resources

The thin layer of soil at the surface of the earth functions as the central resource for sustaining life. Soil management is one of the critical factors controlling plant production, which in turn supports animal production. Soils also remove impurities, protecting water and air quality. A balance must be reached between the short-term use of the soil and the long-term sustainability of this critical resource. Protecting, preserving, and enhancing the soil resource are key elements of this component of the NP212 National Program.

Research is conducted to understand soil physical, chemical, and biological properties and processes, to facilitate the development of soil management practices that overcome limitations to productivity and to improve soil, water and air quality. However, an increasing emphasis will be placed on understanding the ecology of the soil/water/plant system and enhancing the health, quality, and environmental services provided by soils.

Review articles in *Science* magazine and a 2009 report on Frontiers in Soil Science by the National Academy of Sciences have drawn attention to the importance of the soil resource and to our incomplete knowledge of soil properties, processes and functions. Considerable research will be needed to support management practices and systems that can overcome soil limitations to crop production and provide soil, water and air quality benefits.

Selected Accomplishments: Soils Research

Herbicides affect nutrient cycling. Farmers have observed symptoms of nutrient deficiency in crops where the herbicide glyphosate has been used for several years in a row. ARS scientists in West Lafayette, IN found that one reason for this is that long-term exposure to glyphosate affects soil enzyme activities that are critical in nutrient cycling. Depending on how widespread this impact is, these findings could impact fertilizer application rate and weed management decision making for some crop-soil type combinations.

No evidence found that Bt corn residues decompose more slowly than Non-Bt residues. Since Bt corn was introduced, there have been informal and formal communications circulating in the agricultural community that Bt corn residues were more resistant to decomposition than non-Bt corn residues. ARS scientists at Brookings, SD, have completed a series of studies that found no evidence that the decomposition of corn residues was linked to the presence of the Bt gene in the corn hybrid. These studies examined multiple corn hybrids from a single manufacturer, hybrids from different seed manufacturers, and hybrids grown under conditions of differential insect pressure. With the rapid expansion of genetically-modified crops, controlled studies evaluating the potential for unintended effects due to genetic modification provide a firm basis for evaluating the advantages and disadvantages of this technology.

Fungicide use substantially slows degradation of a widely used weed control product. Pesticides are a diverse group of chemicals including products used to control weeds (herbicides), plant diseases (fungicides), and insects (insecticides). During large-scale production of most crops, pesticides from one or more of these classes are applied to farm fields. A common scenario in peanut production in the southeastern U.S. is herbicide application at planting followed by fungicide applications after the crop emerges. Fungicides may alter and impact soil microbial communities, thus there is a potential to impact herbicide degradation, and change herbicide efficacy and environmental fate characteristics. ARS researchers at the Southeast Watershed Research Laboratory in Tifton, GA evaluated potential impacts of four fungicides widely used by peanut growers on the soil persistence of a commonly used herbicide (metolochlor). One of the fungicides was found to double the time the herbicide persisted in soil. This information is of considerable value to peanut growers and other farmers in the region who use these chemicals. Modified farming practices, such as reducing herbicide application rates, may need to be considered where the fungicide and herbicide are used in combination.

Speeding up soil quality recovery in sandy soils under dryland production. Since the 1940s, much of the land in the Southern High Plains region has been planted solely to cotton using conventional tillage practices, resulting in declining soil quality. To sustain future agricultural activities in this area, conservation practices such as minimum tillage and cotton rotations with sorghum are being implemented to reduce erosion and restore soil quality in dryland production. However, it often takes many years before improvements can be seen. ARS scientists at Lubbock, TX found that introducing a rotation of cotton with high biomass crops, such as forage sorghum and a winter rye cover crop, produced increases in microbial biomass carbon and nitrogen, and the activities of enzymes important for nutrient cycling, in as little as three years. It took over five years to show improvements under rotations of cotton and grain sorghum compared to cotton monoculture. This is new information that growers and researchers can consider when identifying cropping systems that will result in improved soil quality and functioning.

Physical/chemical fractionation procedures developed for soil organic matter **characterization.** The complex nature of soil organic matter (SOM) was more completely characterized using innovative physical/chemical fractionation procedures in combination with state-of-the-art spectroscopic techniques. ARS scientists in Ames, IA devised an innovative, integrated SOM fractionation/characterization procedure that permitted sequential isolation of SOM fractions obtained using physical or chemical separation of the same soil sample. Multiple laboratory analyses were used to characterize and compare elemental and chemical composition of several physically- or chemically-defined SOM fractions with whole SOM. This method is being used to detect subtle differences in carbon pools and nutrient cycling due to soil and crop management, such as tillage, crop rotation, cover crops, and bioenergy feedstock production.

Biochar can be used to increase carbon storage and improve soil quality in Midwestern fields. Biochar is a form of charcoal produced while making renewable biofuels through the process of pyrolysis. ARS scientists in Ames, IA, conducted laboratory and field studies to determine how biochar affected several soil biological, chemical, and physical properties in a typical agricultural soil. The laboratory study showed that applying biochar decreased soil compaction, increased soil acidification, and increased the capacity of soil to hold water and plant nutrients compared to soils that did not receive biochar. Applying biochar increased total nitrogen by as much as 7%, organic carbon by as much as up to 69%, and the quantity of several other plant nutrients compared to the unamended soil. These results are important because pyrolysis produces a co-product that can be used to increase soil carbon storage and improve other soil properties and processes (i.e., soil quality).

Improved productivity of sandy coastal soils. Because the southeastern U.S. Coastal Plain is hot and wet, its weathered sandy soils have low organic carbon contents and poor productivity. A study was conducted to test the potential benefits of soil additions of biochar. ARS researchers at Florence, SC, added C to a coastal soil in the form of non-activated pecan biochar and, as a comparison with a more conventional carbon source, finely ground switchgrass. Both biochar and switchgrass additions decreased soil compaction. Switchgrass additions, however, also increased the water holding capacity of the soil while the biochar additions did not. These improvements enhance the quality of these degraded and weathered sandy soils and help sequester carbon.

Cost of nutrient losses in furrow irrigation runoff. Nutrients in furrow irrigation runoff are a lost resource. ARS researchers at Kimberly, ID, measured the amount of phosphorus, inorganic nitrogen, and potassium lost in runoff from furrow-irrigated fields that were fertilized either conventionally or with manure. Most of the nutrient loss was phosphorus, and most of the phosphorus loss was associated with sediment. Less than 3% of the applied nitrogen was lost (2.7% of total inorganic N applied to fertilizer plots, 1.5% of total N applied on manure plots). About one third of the phosphorus applied with the manure was lost with runoff during the two-year study (84 lb P/acre lost out of 219 lb P/acre applied in two years). No phosphorus was applied to the fertilizer or control treatments, which had losses of 33 to 48 lb P/acre /year. The cost to replace nitrate, ammonia, potassium and phosphorus from control plots averaged $35/acre/year; and $40/acre/year for fertilizer and manure treatments. This research underscores the need for management practices to reduce nutrient losses from furrow-irrigated soils.

Corn yield increased by applying fertilizer with strip tillage. Strip tillage is a conservation practice that can incorporate fertilizer into the soil while leaving much of the surface undisturbed. This tillage practice can potentially increase corn yield by applying fertilizer directly beneath the corn row. ARS researchers at Kimberly, ID, determined that applying nitrogen and phosphorus fertilizer with strip tillage increased corn yield on eroded soils 12% compared to broadcast fertilizer application, and 26% compared to surface banding with the planter. Reduced tillage costs and potential increased corn yield with strip tillage could increase the economic productivity of eroded land in the Pacific Northwest.