FY2014 Annual Report
National Program 212 – Climate Change, Soils, and Air Emissions

Introduction

National Program (NP) 212, Climate Change, Soils and Emissions conducts 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 result from 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 in precipitation and temperature patterns, and increased atmospheric carbon dioxide (CO_2) concentration. The impacts of climate change create challenges to agriculture and its soil resources, and also offer new opportunities for agricultural production and enhancement of soil quality.

Soils are a crucial boundary resource for 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.

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 and remote sensing of soil moisture 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 data bases will enhance synthesis and integration analyses and expand research opportunities.

The NP212 Action Plan contains four research components:

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

During FY 2014, 94 full-time scientists working at 28 locations across the U.S. actively engaged in 35 ARS-led and 124 cooperative research projects in NP212. ARS-lead projects were approved through the ARS Office of Scientific Quality Review in late 2010, making this the fourth year of implementation of these five-year projects. The gross fiscal year 2014 funding for NP212 was $49 million.

New additions to the NP212 team in 2014 are:

- **Hakan Buyukcangaz**t from Uludag University in Bursa, Turkey, a visiting scientist at the National Laboratory for Agriculture and the Environment in Ames, IA, is working on the evaluation of the energy balance and evapotranspiration from corn and soybeans in central Iowa to determine how these factors have changed in response to changes in seasonal weather during the last 10 years.
- **Alisa Coffin** has joined the Southeast Watershed Research Laboratory in Tifton, GA as a post-doc. Dr. Coffin has a Ph.D. in Geography with a background in landscape ecology. Her expertise is remote sensing, GIS, spatial statistics and network analysis.
- **Harold Collins**, joined the NP212 team at the Grassland, Soil and Water Research Laboratory, Temple, TX. Hal came to Temple from USDA-ARS, Vegetable and Forage Crops Research Unit, Prosser, WA and is a soil microbiologist conducting research on microbial mediated soil productivity, nutrient cycling of organic amendments, and greenhouse gas emissions.
- **Christian Dold**, graduate of the University of Boon, has joined the National Laboratory for Agriculture and the Environment in Ames, IA, to evaluate the impacts of climate variation on specialty crops in the Midwest and potential adaptation strategies to reduce climate impacts, has joined the . He will be evaluating the effects of temperature and water stress on specialty crops and working on the application of seasonal forecasts to help improve management decisions.
- **Bablu Sharma**, graduate of Texas Tech University, at the National Laboratory for Agriculture and the Environment in Ames, IA, to work on the impacts of management practices to reduce the impact of climate variation in corn and soybean production systems. He will be incorporating the use of remote sensing to evaluate growth response of corn and soybeans in response to management and weather.
- **Heather Tyler**, Stoneville, MS, joined the Crop Production Systems Research Unit, Stoneville, MS. She received her Ph.D. from the University of Florida in 2009 and previously served as a post-doc at the ARS National Sedimentation Laboratory, Oxford, MS. Her research will focus on the impact of herbicide use on the microbial communities associated with transgenic crops.
- **Heidi Waldrip** joined the Livestock Nutrient Management Research Unit in Bushland, TX, as a Research Chemist after serving as a post-doc at the location. She has a Ph.D. in soil science from the University of Maine and is now focused on characterizing the fertilizer value of open-lot feedyard and dairy manures, and in

developing mechanistic models to estimate greenhouse gas and ammonia emissions from beef cattle feedyards and open-lot dairies.
- **Matt Yost** has joined the Cropping Systems & Water Quality Research Unit, Columbia, MO. He is a 2013 Ph.D. from University of Minnesota. He is now focused on evaluation of long-term cropping systems over variable landscapes, including assessing bioenergy crops.

The following scientists retired from the ranks in NP212:

- **Tim Gish** of the Hydrology and Remote Sensing Laboratory, Beltsville, MD
- **Bob Kremer**, Research Microbiologist, from the Cropping Systems & Water Quality Research Unit, Columbia, MO
- **Gary Varvel** of the Agroecosystem Management Research Unit, Lincoln, NE

NP212 lost the following scientists in 2014:

- **William Hunter,** of the Soil, Plant and Nutrient Research Unit, Fort Collins, CO passed away in May 2014.
- **Jeffrey Smith,** of the Soil, Plant and Nutrient Research Unit, Fort Collins, CO passed away in January 2014.

The distinguished record of service of these scientists is recognized world-wide, and they will be missed in NP212.

The following scientists in NP 212 received prominent awards in 2014:

- **Jerry Hatfield**, of the National Laboratory for Agriculture and the Environment in Ames, IA, received an award for Outstanding Research Paper for Quality and Impact, from the Soil and Water Conservation Society, and was elected to the ARS Science Hall of Fame.
- **Doug Karlen,** of the National Laboratory for Agriculture and the Environment in Ames, IA, received the Environmental Quality Award from the American Society of Agronomy, and the Soil Science Research Award from the Soil Science Society of America.
- **Newell Kitchen** of the Cropping Systems & Water Quality Research Unit, Columbia, MO received the American Society of Agronomy 2014 Precision Agriculture Impact Award in recognition of outstanding contributions to extended service to precision agriculture.
- **John Sadler** of the Cropping Systems & Water Quality Research Unit, Columbia, MO, received the Administrator’s Award in September 2014 for his work on the Capital Investment Strategy.

- **Ken Sudduth** of the Cropping Systems & Water Quality Research Unit, Columbia, MO, was awarded the honorary title of Visiting Professor by Hubei University of Arts and Science, Xiang Yang, Hubei Province, China.
- **Rodney Venterea** of the Soil & Water Management Research Unit in St. Paul, MN, was named a Fellow of the Soil Science Society of America.
- **Scott Yates** of the Contaminant Fate and Transport Research Unit, Riverside, CA and **Sharon Papiernik**, Brookings, SD, were recipients of an Outstanding Partnership Award for the ASTM Film Permeability Inter-laboratory Study (Round Robin) from the Federal Laboratory Consortium for Technology Transfer.
- **Scott Yates,** Riverside, CA received the 2014 Innovation in Chemistry of Agriculture Award from the American Chemical Society.

The quality and impact of NP 212 research was further evidenced in 2014 by the following:

- 174 refereed journal articles published
- A new patent application and four new invention disclosures submitted
- Four current cooperative research and development agreements with stakeholders
- Five new material transfer agreements
- Thirty-five new scientific technologies developed, and
- Administration or development of six web sites for academia or stakeholders.

In 2014 NP 212 scientists participated in research collaborations with scientists in: Afghanistan, Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Colombia, Czech Republic, Denmark, Ecuador, Ethiopia, Federated States of Micronesia, Finland, France, Germany, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kenya, Mexico, Mongolia, Namibia, Netherlands, New Zealand, Nigeria, Pakistan, Palestine, Peru, Philippines, Portugal, Russia, Saudi Arabia, Senegal, South Africa, South Korea, Spain, Switzerland, Taiwan, Tanzania, Thailand, Tunisia, Turkey, United Kingdom, Uruguay, and Uzbekistan.

NP 212 Accomplishments for FY2014

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.

Selected Accomplishments

***Inventory of U.S. Greenhouse Gas Emissions and Sinks* released.** Most nations use simple Intergovernmental Panel on Climate Change Tier 1 methodology based on emission factors to estimate greenhouse gas (GHG) fluxes from agricultural systems for national inventories reported to the United Nations Framework Convention on Climate Change. In contrast, the U.S. uses a Tier 3 approach employing the DayCent agro-ecosystem model which was developed by researchers from ARS in Fort Collins, Colorado, and Colorado State University. In 2014, the U.S. Environmental Protection Agency (EPA) published the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012* using DayCent-generated estimates of GHG soil fluxes at state and national scales. These estimates have smaller uncertainty intervals than emissions reported in previous EPA inventories, thus providing more accurate information for this international reporting of GHG emissions.

New method for measuring the permeability of films used for soil fumigation. ARS scientists in Riverside, California and Brookings, South Dakota have developed, tested and published a new American Society for Testing and Materials (ASTM) Standard Method (ASTM E2945–14) to test and accurately measure the permeability of agricultural films to fumigant gases. The EPA requested a standardized methodology to assist their regulatory efforts. ARS scientists conducted round-robin laboratory testing to demonstrate the accuracy, reliability and robustness of their measurement method. After analyzing the results, an experimental protocol was developed which formed the basis of the ASTM Method. The results show that the method performs well for both experienced and first-time film testers across a wide range of film materials and film permeability values (i.e., 4 orders of magnitude). The method has been demonstrated and accepted by many stakeholder groups, e.g. California Department Pesticide Regulation, EPA, and many film manufacturers. This technology transfer provides stakeholders and growers with a reliable method to reduce atmospheric emissions of soil fumigants and helps growers to obtain emission credits that reduce the size of buffer zones surrounding treated fields to increase agricultural production and profit.

Nematodes can be controlled with soil solarization at lower fumigation rates. Methyl iodide, 1,3-dichloropropene and chloropicrin are agricultural fumigants used to kill pests in soil prior to planting crops. However, high emission rates can negatively impact regional air quality and seriously affect individuals living in contaminated air-sheds. Using a lower fumigation application rate is one way to reduce emissions, but may prove inadequate for pest control. ARS scientists at Riverside, California, demonstrated that a reduced rate of soil fumigation (e.g., 70% of a traditional rate) after solarization and/or applying solar-heated water to the soil under plastic film reduced emissions to the atmosphere to as low as 1% (as compared to 30–50% for traditional fumigation). Parasitic nematode control was actually improved by soil heating, even at lower fumigation rates. This information provides producers with a more economical and environmentally sustainable practice for pest control.

New accurate dust emissions data saves ginning industry millions. New regulations for dust smaller than 2.5 micrometers (PM2.5) posed a significant problem to the U.S. cotton ginning industry because emissions data for this size of dust was not available. In response to the new regulations and the lack of cotton gin PM2.5 emissions data, regulators in California attempted to make assumptions on the amount of PM2.5 emitted by gins during the air quality permitting process. ARS researchers from Lubbock, Texas; Las Cruces, New Mexico; and Stoneville, Mississippi, and researchers from Oklahoma State University conducted a four-year, nationwide cotton gin sampling campaign that yielded accurate emissions data for all regulated sizes of dust – including PM2.5. This newly published data was adopted by regulators in California and several other states and has been used in the permitting process for hundreds of gins across the U.S. cotton belt. Use of the new, more accurate data from this study has saved recently permitted ginning facilities from having to install additional dust control measures at a cost of several hundred thousand dollars per facility.

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

Agriculture GHG emissions to the atmosphere are among the documented anthropogenic factors driving climate change. 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.

Selected Accomplishments

Switchgrass and corn residue contribute to U.S. energy and environmental goals. ARS scientists in Lincoln, Nebraska collected data on grain and biomass yield, composition, soil carbon, and production input in order to estimate ethanol yield per acre and greenhouse gas emissions from a long-term corn (with and without corn residue harvest) and switchgrass field trial in the western Corn Belt of the U.S. Soil carbon storage in fields planted to corn or switchgrass resulted in large greenhouse gas emission mitigation potential and demonstrated why proper accounting of soil carbon storage will be critical in determining biofuel carbon intensities. Switchgrass, under optimal management, produced higher ethanol yields than the corn grain-only harvests and similar ethanol yields as corn grain with residue removal. Future integration of cellulosic ethanol biorefineries with corn grain ethanol facilities would result in improved energy efficiency for the current corn grain ethanol system.

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.

Selected Accomplishments

Determination of the "upper lethal growing season average air temperature" for wheat. Adapting wheat production to conditions associated with climate change will require determining how higher temperatures affect wheat and incorporating this knowledge into growth models. ARS scientists in Maricopa, Arizona, in collaboration with scientists at the University of Arizona in Tucson, conducted a "Hot Serial Cereal Experiment." On six planting dates for the experimental wheat crops, infrared heaters were deployed above some of the plots to provide additional warming. Results showed that yields decreased as season average air temperatures increased above 15°C, and that crops failed once temperatures reached 32°C. These results provide much needed information on the environmental limits for wheat production and will serve as a benchmark for researchers developing new varieties and new management strategies for adapting wheat to the higher air temperatures resulting from global change. This research also provides more realistic projections of future climate change effects on wheat, and data for the Agricultural Model Intercomparison and Improvement Project (AgMIP).

Determination of global climate change impacts on grain sorghum productivity in western North America. Projected climate change will likely alter atmospheric CO_2 concentration, ambient temperature, and precipitation patterns. ARS scientists in Maricopa, Arizona, in collaboration with scientists from Chonnam National University in

Korea and the University of Arizona, calibrated and validated a sorghum crop model with an experimental database. The model was then applied to simulate possible effects of climate change on sorghum grain yield and water use efficiency in western North America for the years 2008-2010. Simulated grain yield, growth, and water use of sorghum were in agreement with the corresponding measurements, respectively. Neither simulated nor measured yields responded to elevated CO_2, but both were sensitive to water supply and temperature. This information should ultimately result in better options for producers and stakeholders to mitigate and adapt to projected climate change.

Rising atmospheric carbon dioxide leads to longer growing seasons: While longer growing seasons around the world have been attributed to climate warming over the past century, new research by ARS scientists in Fort Collins, Colorado suggest another factor may be involved. A unique climate change experiment undertaken in native prairie at the High Plains Grassland Research Station near Cheyenne, Wyoming revealed that artificially raising the ambient temperature of the prairie vegetation 3-5° F - levels expected by the end of this century - did increase the length of the growing season, but the response was more pronounced when accompanied by an increase in the ambient carbon dioxide concentration from the present-day level of 400 parts per million (ppm) to 600 ppm. Carbon dioxide is known to increase plant water use efficiency, and the group showed that lower consumptive plant water use in plots exposed to both artificial warming and carbon dioxide enrichment conserved soil moisture, allowing the plants to grow later into the fall. These results, which suggest that growing seasons in water-limited ecosystems may lengthen due to both warming and elevated CO_2, will be critical in developing adaptive management and genetic strategies to climate change.

The Southeast Regional Climate Hub (SERCH) was formed. This Hub serves to connect public, academic, and private sector organizations, researchers, and outreach specialists in order to deliver technical support and provide tools and strategies for climate change response to help producers cope with challenges associated with drought, heat stress, excessive moisture, longer growing seasons, and changes in pest pressures. ARS scientists in Raleigh, North Carolina worked together with scientists from the USDA Forest Service and the USDA Natural Resources Conservation Service to establish a regional climate hub to deliver science-based knowledge and practical information on climate variability to farmers, ranchers, and forest land managers. The SERCH will enable the public to become better informed on climate variability.

Component 4: Maintaining and Enhancing Soil Resources

Soil productivity must be enhanced to meet increasing global food, feed, fiber, and fuel demands. 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.

Selected Accomplishments

A new and revised Kentucky Nitrogen and Phosphorous Index tool. The new and revised Kentucky Nitrogen and Phosphorous Index tool, which was developed by ARS scientists in Ft. Collins, CO, was transferred to the state of Kentucky. Losses of reactive nitrogen and phosphorus are impacting water quality, and there is a need to reduce the off-site transport of these nutrients. The Kentucky Natural Resources Conservation Service reviewed the Conservation Practice Standard for Nutrient Management (Code 590) and released a new version of the Standard in March of 2013. The new Kentucky Nitrogen and Phosphorous Index tool was listed in the standard as an official risk assessment tool for the state. The tool was revised and improved during the last year with new capabilities to improve the assessment of the effects of management on nitrogen and phosphorous losses. This new, revised technology, which is quick and easy to use, and can assess the potential risk of N and P losses to the environment, is in use by the Kentucky NRCS (http://www.ars.usda.gov/npa/spnr/nitrogentools).

Corn stover harvest effects on nutrient concentrations in central Iowa. Proponents of cellulosic biofuel need to understand how soil nutrient levels will be affected by removing corn stover for use as feedstock for cellulosic biofuel. More than 500 site-years of corn plant samples were collected by ARS scientists in Ames, Iowa, who divided plant samples into different parts. All samples were analyzed to determine nutrient concentrations. The results showed that compared to harvesting only the grain, harvesting corn stover increased nitrogen, phosphorus, and potassium loss by 14, 1.4, and 16 pounds per ton, respectively. The losses of nitrogen and phosphorus are not considered enough to change current nitrogen and phosphorus fertilization practices for stover harvest rates of one ton/acre. However, the potassium loss is sufficiently high to warrant routine soil testing and plant analysis to monitor available potassium levels. This information provides guidelines for the acquisition of sufficient feedstock supplies to operate emerging cellulosic biofuel investments in a sustainable manner.

Assessing near-surface soil organic carbon across several US cropland watersheds. The Conservation Effects Assessment Project (CEAP) provides a scientific basis for assessing the effectiveness of conservation practices on water and soil quality in the U.S. ARS scientists at Ames, Iowa and West Lafayette, Indiana, analyzed surface soil samples from 12 cropland watersheds from Georgia to Texas and used the Soil Management Assessment Framework (SMAF) to score the measured soil data so that climate and inherent soil properties would be taken into account. A high score is associated with high productivity and minimal environmental impact. Measured soil organic carbon (SOC) contents ranged from 3.0 to 21.7 g kg-1 and SMAF-SOC scores ranged from 0.09 to 1.00, which is the optimum. This assessment showed that SOC evaluations need to be soil- and site-specific because many factors, including environmental influences and inherent soil characteristics influence SOC levels. This is important because increasing, or at least maintaining SOC levels is critical to sustaining crop productivity. Higher levels of SOC increase nutrient availability, water infiltration, and water holding capacity, and ultimately decreases soil erosion and improves soil health.

Watershed-scale monitoring of soil quality/health is feasible and useful. Soil quality (SQ) assessments were incorporated into the ARS Cropland CEAP in 2006 so that their effectiveness for evaluating conservation and other soil management practices would be determined. ARS scientists in Ames, Iowa, measured ten SQ indicators within 600 soil samples of the 0 to 5-cm (0 to 2 inch) depth increment and 398 soil samples of the 5 to 15-cm (2 to 6 inch) depth increment that were collected within five ARS Cropland CEAP watersheds. Results were evaluated statistically and scored to provide a soil quality index (SQI) using the SMAF. Microbial biomass carbon (MBC) was significantly affected by crop rotation at both sampling depths and by location within the surface 5 cm. Beta-glucosidase (BG) levels were significantly affected by location, crop rotation, manure, and tillage histories within the 0 to 5-cm increment. These active carbon fractions (MBC and BG) were more sensitive indicators than soil organic carbon (SOC). This information will help producers and conservationists develop land management practices that will prevent further degradation of our nation's fragile soil resources.

Cover crops protect soil health. Corn stover (corn stalks and leaves, not harvested with grain) is a potentially valuable biofuel feedstock. It is important to understand the implications of removing the stover to establish guidelines that protect soil health and the long-term sustainability of the biofuel industry. The feasibility of stover removal is being evaluated in studies being conducted by the USDA in collaboration with universities in various regions of the United States. ARS researchers in Brookings, South Dakota collaborated with other ARS researchers to show that removing corn stover has a negative impact on soil health, but that these impacts can be reduced by using cover crops and no-till management. Soil microbial communities were influenced by corn stover removal, but the effects were slow and relatively minor in no-till systems. If corn stover was removed, cover crops provided critical components that maintain soil structure, physically protect soil from erosion, and buffer the response of soil microbes. This research is part of a national effort to define areas of the U.S. where removing corn residue is feasible, harvest rates that avoid detrimental effects on our soil resource, and management practices, like cover crops, that can help overcome the negative effects of removing crop residues.

Improved crop yields with reduced inputs. Producers are exploring ways to reduce inputs in their production systems, for both economic and environmental reasons. No-till management enables producers to reduce inputs in corn production and generally improves soil health. ARS scientists at Brookings, South Dakota, comparing a no-till production system to the conventional tillage-based system, found that corn yield in no-till was 6% higher than the conventional system across 6 years, but used 20-30% less water, seed, fertilizer, and herbicide. These results suggest that no-till corn production uses resources more efficiently and provides opportunities to improve farm profitability and reduce environmental impacts.