FY2011 Annual Report
National Program 212 – Climate Change, Soils, and Emissions

Introduction

National Program (NP) 212, Climate Change, Soils and Emissions Research 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 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 (CO2) concentration. The impacts of climate change create challenges to agriculture and its soil resources, 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.

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 data bases will enhance synthesis and integration analyses and expand research opportunities.

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

Herbicide volatilization exceeds herbicide runoff losses. Surface runoff was thought to be the major off-site transport mechanism for herbicide. However, until recently no field investigations monitored both surface runoff and turbulent volatilization fluxes simultaneously. An 8-year, field-scale experiment in Beltsville, Maryland was conducted where herbicide (atrazine and metolachlor) volatilization and surface runoff losses were simultaneously monitored and evaluated. Results demonstrate that regardless of weather conditions, volatilization losses consistently exceeded surface runoff losses. Surprisingly, herbicide volatilization losses were up to 25 times larger than herbicide surface runoff losses. The research will affect USDA and USEPA policy with regard to herbicide behavior and the data will be used to develop or improve pesticide behavior models.

Assessed the benefits of new manure application methods. In a well managed animal production system, manure nutrients are returned to the soil where they are used to produce feed crops for the animals. During this cycle though, losses occur in the form of gaseous emissions, leaching to groundwater, and runoff in surface water. ARS scientists at University Park, PA, with collaboration from the Pennsylvania State University verified a farm model to appropriately represent several manure application methods and then used the model to assess and compare their long term environmental and economic impacts on farms. Use of a shallow disk injection device for applying manure below the soil surface generally provided the lowest nutrient losses without substantially reducing farm profit. This new information is guiding animal producers and policymakers in the Chesapeake Bay region toward manure application technologies that simultaneously reduce environmental impact and maintain or improve farm profit.

New mathematical model accurately predicts pest control and emissions of soil fumigants to the atmosphere. The use of soil fumigants is an important component of U.S. agriculture but fumigants have the potential to pollute the atmosphere; new methods are needed to ensure crop protection while minimizing atmospheric emissions. Experiments conducted at U.S. Salinity Laboratory demonstrate that a predictive model could be used to simultaneously estimate fumigant emissions and the control of plant pest organisms in field soil. The results show that the model accurately predicted both emissions and pest control and provides a new approach to optimize fumigant applications that ensure crop protection while minimizing atmospheric emissions. This methodology could be very valuable to growers in need of tools to manage soil fumigants and plant pests.

Cotton gin particulate matter emissions measurements. The cotton ginning industry was turned upside down in 2006 when EPA mandated that the amount of PM2.5 emissions be reduced by nearly half. The offending PM2.5 emissions are particles less than 1/30th the thickness of a human hair, basically a very fine dust produced during the ginning process. With no real emissions data on this agricultural operation, state regulatory agencies have been scrambling to determine levels of these small particles other than best-guess, which could lead to overestimation and an unnecessary burden imposed on the industry, not to mention possible fines. In a collaborative effort, ARS researchers in Mesilla Park, NM; Stoneville, MS; and Lubbock, TX, and Oklahoma State University researchers in Stillwater, OK, are in the third year of a four-year industry-supported project to measure emissions from gins across the country. Earlier this year when California action agencies had to show EPA progress on implementing a regulatory program, all involved with the gin emissions study were able to agree upon and compile scientifically supported preliminary PM2.5 emissions information from four of the total seven gins scheduled to be sampled for the project. This information met the immediate needs of the California regulators, and is a model of how scientist and agriculture working with state and federal regulators can collaborate to provide scientifically-sound emissions data. At the end of the day, regulatory agencies were provided with data that accurately represents PM2.5 emissions from US cotton gins, thus assuring a sound basis for setting and enforcing regulations.

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

Nitrogen fertilizer source influences nitrous oxide emissions from strip-till corn. Nitrous oxide (N2O) is a potent greenhouse gas emitted when inorganic N fertilizers are applied to agricultural crops. ARS Scientists in Fort Collins, CO, compared N2O emissions from alternative N fertilizer sources to commonly used granular urea and liquid urea-ammonium nitrate (UAN) fertilizers in an irrigated, strip-till corn system. Some alternative N sources reduced growing season N2O emissions up to 70% compared to urea, and 49% compared to UAN. Cropping system managers and policy makers can now consider selection of N fertilizer source as a mitigation practice for reducing N2O emissions and global warming potential for the semi-arid western U.S.

Web-based Book of GRACEnet Soil Carbon Sampling Protocols. The Greenhouse Gas Reduction through Agricultural Carbon Enhancement network (GRACEnet) is a coordinated national effort that was established during 2005 by the USDA - Agricultural Research Service. As part of this effort guidelines were established to enable research collaborations and common sampling and sample collection protocols across many locations and within different agro-ecosystems to assess the soil carbon consequences of agricultural management systems at local, regional, and national scale. The use of common management scenarios, consistent sampling protocols, and detailed record keeping facilitates cross-location and cross-regional comparisons and ensures quality control even with location-specific soils, crops and conditions. The chapters in this book were prepared by leading ARS scientists. It is located on the ARS GRACEnet website < http://www.ars.usda.gov/research/GRACEnet > and is freely available to anyone visiting the website. Copies on CD have also been shared with the 31 countries of the Global Research Alliance (GRA) on Agricultural Greenhouse Gases, who are considering the use of these protocols worldwide. The availability of these protocols enable comparison of soil carbon across space and time, thus enabling collaboration on the development of management practices to help mitigate atmospheric CO2 emissions from world-wide agriculture systems.

U.S. Agriculture and Forestry Greenhouse Gas Inventory published by USDA. Interest in climate change and efforts to reduce the environmental impacts of agricultural production systems highlight the need for more accurate methods to quantify greenhouse gas emissions from the US agricultural sector. The recently published U.S. Agriculture and Forestry Greenhouse Gas Inventory 1990-2008 feature state of the art methods to calculate emissions and their associated uncertainty ranges. The report partitions emissions spatially and by source category so policy makers can identify where mitigation efforts should be targeted. Results from this inventory are also included in the annual Inventory of US Greenhouse Gas Emissions and Sinks published by EPA and reported to The United Nations Framework Convention on Climate Change (UNFCCC). The website hosting the report has received several hundred visits per month.

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

Carbon dioxide eliminates desiccation in warmed semi-arid rangelands. Climate change is expected to bring warmer, desiccating conditions to many world rangelands. However, many analyses have not considered the direct effect of rising CO2, which ARS scientists hypothesized would positively improve plant water use efficiency, thereby off-setting the negative effects of warming-induced desiccation. ARS scientists in Cheyenne, WY, Fort Collins, CO, and Maricopa, AZ, plus collaborators from the University of Wyoming created an experiment with higher CO2 and slightly warmer temperature conditions expected to occur during the second half of this century. They discovered that combined elevated CO2 and warmer temperatures favored growth of warm-season, perennial grasses, and that the additional CO2 completely reversed the desiccating effects of the warmer temperature in a typical native semi-arid prairie environment. These results are helping climate change scientists make better predictions about how rising CO2 will affect the responses of rangelands to climate change, and are being used to develop climate change adaptive management strategies for ranchers and public land managers.

Physiological basis for differential productivity in switchgrass ecotypes. Switchgrass, a native grass in the U.S. has gained large popularity as a biomass crop for bioenergy. It is adapted to a wide range of environments; however, its productivity declines the further north it is grown within its native range. ARS Researchers at Morris, MN, discovered that when moved from near ideal to low growth temperatures, varieties of switchgrass adapted to different parts of the U.S. did not acclimate photosynthetically but instead they adjusted the way they made and used sugars such that some grew better than others at cooler than ideal temperatures. Notably, a southern variety was found to produce more biomass than northern varieties, even at low temperatures. This was partly because it made more sugar for growth (sucrose) than storage (starch) than other varieties did. The information greatly helps other scientists, especially plant geneticists, developing more productive switchgrass varieties for bioenergy.

Effects of warmer air temperatures on crop growth, development, ecophysiology and yield. To determine how increasing air temperatures may affect future crop yields, ARS scientists from the U.S. Arid-Land Agricultural Research Center, Maricopa, AZ and the University of Arizona used infrared heaters and varied planting dates to expose wheat crops to an unusually wide range of temperatures. The effects of higher air temperature on wheat yield varied due to interacting effects of planting date, risk of frost, and the response of crop photosynthesis, water use and duration of wheat crops. For two planting dates, warming protected the developing wheat grain heads from frost damage and led to good yields, while lower ambient air temperature plots produced no grain. The results indicate that increasing air temperatures using current management and/or cultivars will likely decrease wheat yields in irrigated systems of Arizona and California. However, if warming is sufficient to reduce the risk of frost, growers might plant wheat earlier, thus extending the wheat growing season and either stabilizing or increasing wheat yields. This information provides insights needed to develop adaptation strategies for adapting agricultural production to changing climate conditions.

Corn water use efficiency increases under elevated CO2. Water availability for agriculture is expected to decline as atmospheric CO2 increases in the future. Thus, it is important to understand how plants grown under elevated CO2 will respond to water stress. ARS scientists in the Crop Systems and Global Change Laboratory, Beltsville, MD, investigated the relationship between plant growth and water use for a corn crop in soilbins housed in sun-lit growth chambers under two CO2 concentrations. Soil water contents observed under elevated CO2 were higher than those grown under ambient CO2 concentrations even though less irrigation water was applied. The corn grown under elevated CO2 used up to 20% less water than corn grown under ambient CO2 levels. This information provides information for researchers, growers and agricultural policy makers to devise strategies for adapting agricultural production to changing climate conditions.

Improved nitrogen management tool released online. Nitrogen losses from agricultural systems impact soil, water, and air quality. There is a need for new tools that can help assess reactive nitrogen losses from agricultural systems. New USDA-ARS tools such as the Nitrogen Trading Tool, Nitrogen Index 4.3, and NLEAP-GIS 4.2 were calibrated and validated, and were released in December 2010 via a new ARS webpage (http://www.ars.usda.gov/npa/spnr/nitrogentools). These tools have been downloaded hundreds of times and are being used by international agencies, universities, and national and international peers to assess the effects of management practices on nitrogen losses in order to reduce these losses to the environment. .

Environmental impacts of biofuel feedstock production systems. The Energy Independence and Security Act of 2007 mandates increased production of energy from alternate fuel sources such as biomass. ARS Researchers in Fort Collins, CO, used field data from biofuel feedstock plots in the central and eastern US to verify the ability of a commonly used computer model called DAYCENT to represent the ethanol yields and greenhouse gas emissions for different crops. They then used the model to quantify yields and greenhouse gas emissions for lands currently used for corn ethanol production and to project yields and emissions if this land was converted to cellulosic ethanol production using perennial crops. Results suggest that if land currently used for corn ethanol production were converted to perennial crops, ethanol production could increase from 7 to 12 billion gallons while greenhouse gas emissions from soil would decrease by approximately 400%. These finding are critical for efficient energy production from plant feedstocks for the United States.

Soil Microbial Responses to Elevated Carbon Dioxide and Ozone in a Wheat-Soybean Cropping System. Climate change factors such as rising atmospheric carbon dioxide (CO_2) and ozone can exert significant impacts on crop growth, but how the soil microbes in agricultural systems respond to these factors remains largely unexplored. Using a long-term field study conducted in a no-till wheat-soybean rotation system with open-top chambers, ARS researchers in Raleigh, NC showed that elevated CO_2 stimulated plant biomass production and ozone lowered plant biomass production, but only elevated CO_2 significantly affected soil microbial biomass, respiration and community composition. Enhanced microbial biomass and activity from elevated CO_2 coincided with increased soil nitrogen availability likely due to stimulation of soybean nitrogen-fixation under elevated CO_2. These results highlight the need to consider the interactive effects of carbon and nitrogen availability on microbial activity when projecting soil carbon balance under future CO_2 scenarios. The addition of nitrogen to agricultural systems through fertilizers or legume crops may stimulate microbial decomposition processes and limit carbon sequestration potential. These findings enhance our ability to predict and manage soil carbon sequestration under changing climate conditions.

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

Conservation-based biomass feedstock harvest recommendations. Crop residues are a potential renewable bioenergy feedstock that can produce power, heat and transportation fuels. Crop residues refer to the non-food portion of a crop that remains after grain harvest that protects soil from erosion and builds soil organic matter. Guidelines or recommendations are needed when deciding where, if, and how much residue needs to remain on the land and how much may be harvested. ARS Researchers at Morris, MN, developed recommendations for conservation-based biomass feedstock harvest, which were used to write university and Natural Resources Conservation Service (NRCS) factsheets, and were presented at workshops and field days. These guidelines provide decision tools to producers, consultants, extension and NRCS, and industry for determining where, if, and how much crop residue can be harvested. Furthermore, research-based recommendations were developed for safeguarding soil productivity if residue is harvested so that soils can indefinitely supply food, feed, fiber and fuel.

Greenhouse method to produce sweet corn seedlings well colonized by arbuscular mycorrhizal fungi for organic farming. Growing sweet corn seedlings in greenhouses and transplanting them to the field earlier during the growing season rather than directly sowing seeds in the field, helps farmers take advantage of higher prices paid for early season produce. The greenhouse seedling production also provides an opportunity to inoculate seedlings with arbuscular mycorrhizal (AM) fungi, beneficial soil fungi that colonize roots and enhance crop nutrient uptake, disease resistance, and drought resistance. Unfortunately, the two-week greenhouse growth period can be too short for AM fungi to colonize roots unless optimal conditions exist, thus potentially wasting money and time on inoculation. ARS researchers at Wyndmoor, PA, in cooperation with The Rodale Institute tested different greenhouse nutrient and potting media regimes as a means of accelerating AM fungi colonization of sweet corn seedling roots. A mix of pre-incubation, inoculated potting media containing compost was used to stimulate germination of AM fungi prior to sowing seeds in the greenhouse. A 1:3 mixture of AM inoculum and the potting media was then shown to produce extensive colonization of sweet corn roots within the two-week greenhouse growth period. These results provide a strategy to enable organic and non-organic farmers to utilize AM fungus inoculum for sweet corn production, thus increasing the likelihood of successful sweet corn yields, and increased economic return.

Future Activities

Research conducted for the ARS NP212 Climate Change, Soils and Air Emissions program will continue during coming year with an increased emphasis on synthesis of results and preparation of technology transfer mechanisms. The program will begin an assessment of its most recent five years of research and begin planning the next five year research agenda. A report will be produced summarizing program accomplishments focused on objectives set forth by the 2009-2013 Action Plan. This report will be reviewed by a panel of non-ARS employees as per ARS Office of Scientific Quality Review (OSQR) protocols. The program summary report will be posted on-line.

ARS personnel of the NP212 program are also contributing to a variety of activities of USDA, national and international interest:

- The National Climate Assessment,
- Greenhouse Gas Mitigation Options guidelines for agriculture,
- The National Earth Observations Strategy,
- Development of concepts and algorithms for future earth resource satellites,
- The Global Research Alliance on Agricultural Greenhouse Gases (GRA), (http://www.globalresearchalliance.org/)
- Collaboration with EPA on analysis of data collected for the National Air Emissions Monitoring Study (NAEMS)

Substantial progress was made on data management systems for GRACEnet and REAP during 2011. This effort is continuing.

Research collaborations are being planned with USDA-APHIS, USDA-NRCS, NASA, NOAA, Department of Energy, and Department of Interior among others. There is increasing interest in ARS climate change mitigation and adaptation research, air quality research data and ARS simulation models by domestic and international partners.