FY2012 Annual Report
National Program 212 – Climate Change, Soils, and Air 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 (CO_2) 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.

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.

The Chief of the USDA-Natural Resources Conservation Service convenes the Agricultural Air Quality Task Force (AAQTF), a Federal Advisory Committee that meets twice a year. ARS participates in the AAQTF via an agency seat, and via invited presentations from scientists. The AAQTF is a valuable source of information on stakeholder needs and concerns that provide criteria for decisions about agricultural air quality research conducted by ARS.

Selected Accomplishments

Sensitivity of herbicide volatilization to soil moisture. Efficient herbicide application has been hampered by a lack of understanding of fate and transport mechanisms. Field investigations over the past 14 years by ARS scientists from Beltsville, Maryland, Ames, Iowa and Riverside, California have determined that volatilization (vapor loss to the atmosphere) appears to be the most critical pathway for herbicide loss from production fields into neighboring ecosystems. Herbicide volatilization experiments conducted in Beltsville, Maryland, the longest record of herbicide vapor loss observations worldwide, demonstrated that herbicide volatilization is greatest under warm, wet soil moisture conditions during the day when air near the soil has a tendency to rise as the soil warms. Consequently, all herbicide volatilization models must be revised to account for atmospheric stability and soil moisture conditions. The addition of these terms significantly improves herbicide volatilization models used to help guide herbicide applications on crop fields world-wide. These model improvements have uses in herbicide application practices, as well as USDA and U.S. Environmental Protection Agency policy development, and they show ways to reduce environmental and economic losses incurred with volatilization.

Volatilization moves pesticides through the air into South Florida ecosystems. The health of south Florida ecosystems has been declining due to nutrient and pesticide losses from agricultural activities and urban encroachment. The high humidity and temperatures, frequent rainfall and irrigation, soil type, and soil structure enhance the loss of applied pesticides to the atmosphere for this area. ARS researchers from Beltsville, Maryland and Tifton, Georgia, in collaboration with researchers from the University of Florida, examined the fate of endosulfan, an insecticide previously identified as a potential hazard to aquatic organisms of this region. They discovered that volatilization from the fields, and not drift during application, was by far the most likely emission source to nearby Everglades and Biscayne National Parks. This discovery provides scientists, regulators, extension specialists, and producers information needed to modify agricultural management practices to protect sensitive ecosystems.

Accurate prediction of pest control and emissions of soil fumigants to the atmosphere. Soil fumigants are an important tool for pest control but are also potential atmospheric pollutants. Improved application methods are needed to ensure crop protection while minimizing fumigant losses to the atmosphere. ARS scientists at the U.S. Salinity Laboratory in Riverside, California developed a predictive model that can be used to simultaneously estimate the efficacy of soil-borne pest control and fumigant emissions from field soil. The model provides a new decision support tool for optimizing fumigant application that ensures adequate crop protection while reducing effects on the environment and concomitant economic impact associated with chemical losses.

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.

ARS conducts the Greenhouse gas Reductions through Agricultural Carbon Enhancement network (GRACEnet) project to focus its GHG and carbon sequestration research. The primary objective of GRACEnet is to identify and further develop agricultural practices that will enhance carbon sequestration in soils, promote sustainability and provide a sound scientific basis for carbon credits and trading programs. This program generates information concerning carbon storage in agricultural systems that is needed by producers, program managers and policy makers. GRACEnet also addresses the other greenhouse gases, nitrous oxide and methane that may be emitted by agricultural practices. Agricultural studies by GRACEnet scientists include both grazing lands (range and pasture) and crop lands (irrigated and dryland). Coordinated multi-location field studies follow standardized protocols to compare net GHG emissions (carbon dioxide, nitrous oxide, methane), carbon sequestration, and broad environmental benefits under different management systems including those that a) typify existing production practices, b) maximize C sequestration, c) minimize net GHG emissions, and d) meet sustainable production and broad environmental benefit goals (including C sequestration, net GHG emissions, water, air and soil quality, etc.).

Selected Accomplishments

Major greenhouse gas book published. Concurrent efforts to mitigate agricultural contributions to climate change while adapting to its projected consequences will be essential to ensure long-term sustainability and food security in the U.S. To facilitate successful responses to climate change, USDA-ARS scientists involved in GRACEnet (Greenhouse Gas through Agricultural Carbon Enhancement Network) published a book documenting recent research accomplishments addressing strategies to mitigate and adapt to climate change. The book, entitled *Managing Agricultural Greenhouse Gases: Coordinated Agricultural Research through GRACEnet to Address our Changing Climate*, includes regional syntheses of soil organic carbon and GHG dynamics for broad portfolio of agricultural land uses, as well as additional chapters central to GRACEnet activities (e.g., modeling, method development, economic outcomes of GHG mitigation options, adaptation research, and international collaboration). The book supports ARS's goal of providing knowledge and information on soil carbon sequestration, GHG emissions, and environmental benefits to better implement scientifically-based agricultural management practices from field to national policy scales.

Agriculture greenhouse gas synthesis document produced. The Council for Agricultural Science and Technology **(**CAST) Task Force Report #141 entitled, "Carbon Sequestration and Greenhouse Gas Fluxes in Agriculture: Challenges and Opportunities," was developed by a team of 21 leading scientists under the chairmanship of scientists from ARS and Colorado State University. Globally, agriculture accounts for 13.5% of GHG emissions. In the United States, agriculture is a small but significant component of the country's and world's GHG emissions. This report examines the current science to inform the public and policymakers about this crucial topic. This report's primary focus is on agriculture's role in the land-atmosphere exchanges of GHGs as well as agriculture's ability to decrease GHG emissions or sequester additional carbon in agricultural soils while continuing to supply the necessary food, feed, and fiber required for the world's growing population. Practices are outlined for which increased C sequestration and decreased emissions of GHGs have been established or, in some instances, are presently under investigation. The practices are evaluated and presented in separate sections that cover annual cropland, pasture and range, horticultural crops, agroforestry systems, wetlands and organic soils, confined livestock, and biofuel feedstock production. Data and analysis from the ARS GRACEnet project are frequently cited by the report. The document serves as a statement of the state-of-the-art on GHG emissions from agriculture and is thus a significant source of information for scientists and policy-makers.

Deeper application of fertilizer in soil reduces greenhouse gas emissions when used with no- or reduced-tillage. A major GHG source from cropping systems is nitrous oxide (N_2O) - a by-product of fertilizer use- that is 300 times more effective than CO_2 as a GHG. No tillage (NT) and reduced tillage (RT) are increasingly employed to increase soil carbon storage, decrease soil CO_2 emissions, conserve moisture and reduce erosion, but the effects of NT and RT on N_2O emissions have been inconsistent among studies performed to date. A global meta-analysis of 239 direct comparisons of GHG emissions from Conventional Till (CT) and NT/RT was performed by scientists from ARS in St. Paul, Minnesota, the University of California-Davis and Northern Arizona University. In studies where N fertilizer was initially placed 5 cm or deeper in the soil, N_2O emissions tended to be 25% lower with NT/RT than with CT, especially in humid climates. In contrast, when N fertilizers were placed closer to the soil surface, N_2O emissions tended to be greater or no different with NT/RT than with CT. These results provide a simple means of optimizing tillage and fertilizer management practices to reduce N_2O and CO_2 GHG emissions, while maintaining the other benefits of NT/RT tillage.

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 is co-leading the distributed research collaboration entitled the Agricultural Model Intercomparison and improvement Project, (AgMIP). The goals of AgMIP are to improve substantially the characterization of risk of hunger and world food security due to climate change and to enhance adaptation capacity in both developing and developed countries. The project brings together domestic and international crop modelers to advance crop modeling for specific crops, collect new field data where needed, and build shared data bases for model development and testing. The crop modelers also engage the climate modeling community to enable projections of the future crop yields under different climate scenarios.

Selected Accomplishments

Soil organic matter in grasslands is susceptible to climate change. Soil organic matter (SOM) contributes substantially to the health of rangeland ecosystems. There is a need to understand the long term effects of rising atmospheric carbon dioxide (CO_2) and warmer temperatures associated with climate change on SOM and rangeland plant production. ARS scientists in Cheyenne, Wyoming/Fort Collins, Colorado and collaborators from the University of Wyoming, and the University of Sydney, Australia subjected portions of a mixed-grass prairie to temperature and CO_2 concentrations projected for the next 50 years. Plant production frequently increased with additional CO_2 and warmer temperatures. However, SOM that is typically resistant to decomposition also increased, thus indicating the potential for a decline in soil quality and health of the rangeland ecosystem. These results suggest that rising CO_2 and temperature may increase plant production in this semiarid rangeland ecosystem, with an associated decrease of SOM and long term rangeland ecosystem health.

Larger rainfall events associated with climate change may reduce semiarid rangeland forage quality. The size of individual rain events in semi-arid rangelands can be as important as total annual rainfall in controlling the production and quality of forage for livestock. Nitrogen uptake by plants and soil microbes is important for production and quality of forage. Because shifts toward larger rainfall events are predicted with climate change, ARS researchers in Cheyenne, Wyoming/Fort Collins, Colorado and collaborators from Colorado State University studied how different sized rainfall events affected the uptake of soil nutrients by grass roots and by soil microbes in the shortgrass steppe of eastern Colorado. Results showed that rainfall event size (0.4 or 0.8 inches) did not affect the timing of nitrogen uptake, but did substantially influence whether plants or microbes were more effective in acquiring nitrogen. Plants were most effective in acquiring nitrogen following smaller rainfall events, whereas soil microbes were more effective in acquiring nitrogen following larger rainfall events. Large rainfall events result in more efficient use of water by grasses, and therefore increase the efficiency of forage production. In contrast, smaller rainfall events may be important for plant nitrogen uptake which should maintain high protein concentrations in forage grasses. The findings indicate that predicted shifts toward larger rainfall events with future climate change may increase forage production but decrease forage quality in semiarid rangelands, thus creating a need for supplemental nutrition strategies to maintain livestock production quality.

Elevated atmospheric CO_2 selectively affects the vigor of non-native plants. For some plants, greater atmospheric CO2 promotes larger and more vigorous growth, and while this can increase crop yield, it can also foster an undesired, aggressive spread of non-native plants. Lantana and Vinca, non-native species introduced to the U.S. as ornamentals, were grown in Auburn, AL under elevated CO_2 by ARS researchers. However, Lantana was more responsive to elevated CO_2 than Vinca. Thus, Vinca is less likely to aggressively spread as atmospheric CO_2 increases, whereas Lantana will likely respond to additional atmospheric CO_2 and may require greater effort to control. This study illustrates how non-native species, previously cultivated as non-invasive, have the potential to become invasive as atmospheric CO_2 continues to rise.

Identification of plants that may create management problems under future climate provides a climate change adaptation tool for avoiding unintended consequences of using and/or importing non-native species.

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.

ARS scientists are conducting the Renewable Energy Assessment Project (REAP) to build tools that will enable producers to harvest crop residue for biofuel or forage, while maintaining sustainable soils. Products from this work are 1) guidelines for management practices supporting sustainable harvest of residue, 2) algorithm(s) estimating the amount of crop residue that can be sustainably harvested, and 3) decision support tools and guidelines describing the economic trade-off between residue harvest and retention to sequester soil. Delivery of this knowledge and these products to farmers and the biomass ethanol industry will promote harvest of stover and crop residues in a manner that preserves the capacity our soil to produce food, feed, fiber, and fuel.

Selected Accomplishments

Guidelines for corn stover harvest that maintain soil sustainability. Corn stover (crop residue left on fields following harvest), has been identified as a potential feedstock for producing bioenergy and/or other bioproducts. However, excessive harvest of corn stover may also rob the soil of nutrients and carbon need to maintain healthy, sustainable soil, and thus guidelines for sustainable corn stover harvest are needed. Four years of cooperative field research among ARS scientists in Ames, Iowa, the advanced fuels commercial partnership POET-DSM, and Iowa State University showed that to sustain soil carbon levels and other critical soil functions, corn stover should not be harvested from a field if the average grain yields of the field are less than 11 Mg/ha (175 bu/acre). This information is a key development of ARS Renewable Energy Assessment Project (REAP) team studies and provides a guideline for enabling the U.S. to reach goals for increased bioenergy and bioproduct production from corn stover, while sustaining soil health for future harvests.

Narrow-row planting reduces sediment and herbicide losses from cotton production systems. Changing production practices can improve surface water quality of agricultural lands by reducing runoff containing sediment and agrochemicals. ARS scientists at Stoneville, Mississippi, evaluated sediment and herbicide losses from 4- to 6-leaf cotton planted in narrow and wide rows to determine if a change of row spacing could maintain yields while reducing cultivation impacts on water quality. Planting cotton on flat beds with rows spaced 15-inches apart reduced sediment loss by 38% relative to the losses from cotton planted on raised beds spaced 38-inches apart. Planting cotton in narrow rows also reduced herbicide loss relative to that of wide-row systems given similar factors affecting pesticide movement and runoff.

Converting from wide-to narrow-row cotton cultivation provides a simple means of reducing sediment losses from fields without a reduction of yields, and thus positively impacting Mid-South water quality.

Reduced tillage in dryland cropping systems improves soil quality in less than 10 years. Soil quality indexes are useful metrics of the effects of cover crops and tillage practices on soil and water conservation, and are thus valuable indicators of sustainable soil management needed for a productive and environmentally safe food supply. ARS scientists at Lubbock, Texas measured the effects of tillage, and adding diverse grains and cover crops to dryland cropping systems on soil quality parameters and water infiltration rates after 8 and 10 years of production. Overall, the indexes showed that soil properties were more sensitive to cropping system differences (adding more biomass to a cotton crop rotation was found to improve soil quality), than tillage differences (conventional versus no tillage), and demonstrated the importance of crop rotations for improving soil quality of dryland cropping systems. Although soil microbial properties were not sensitive to tillage practices, measurements related to soil quality, including organic matter content, soil density, wet and dry aggregate stability, and soil strength, showed differences of these systems due to tillage. This study demonstrated that reduced tillage practices can be used to improve soil quality for agricultural production in less than 10 years for dryland cropping systems.)

OTHER ACTIVITIES

ARS personnel of the NP212 program are also contributing to a variety of activities of USDA, national and international interest including the National Earth Observations (NEO) strategy and the National Climate Assessment (NCA). The NEO strategy is assessing the capacity of existing environmental data collection systems (such as satellites and earth surface-based measurement networks) to meet the nation's information needs for decision-making, and to assess future information needs that will affect decisions about the next generation of earth observing satellites and earth surface data collection systems.

Scientists contributing to NP212 are also developing data management systems that will provide long-term stewardship for research data generated in pursuit of NP212 Action Plan Goals. Currently, GRACEnet and REAP have been the focus of this effort.

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 conduct 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. The 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.

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 for agriculture, air quality research data and ARS simulation models by domestic and international partners.