Global Change National Program 204 FY2006 Annual Report

Introduction

Global change refers to large-scale changes of the Earth's biological, geological, hydrological, and atmospheric systems, whether of natural or human origin. Global change is increasingly a topic of concern for agricultural managers and strategic decision makers as the impacts of change are being documented as occurring faster than originally expected by the scientific community.

The ARS Global Change National Program contains four components: Carbon Cycle and Carbon Storage, Trace Gases, Agricultural Ecosystem Impacts, and Changes in Weather and the Water Cycle at Farm, Ranch, and Regional Scales. Over 40 ARS laboratories are conducting research supporting the Global Change National Program. Research is focused on 1) understanding the impacts of global change on agricultural systems, 2) developing management practices for agriculture to adapt and/or mitigate the impacts of change, and 3) developing strategies to mitigate the impact of agricultural practices that may contribute to global climate change. ARS maintains that a predictive understanding of global change effects on agriculture is needed as a basis for development of technologies and policies that will enable farm and ranch adaptation to global change impacts and mitigate factors affecting climate change. The approach for this requires experimental hypothesis testing, development of simulation models and management practices to manage risks associated with anticipated change.

Carbon Cycle and Carbon Storage

The Carbon Cycle and Carbon Storage component seeks to conduct and transfer results of research to identify the best practices for storing carbon from atmospheric carbon dioxide in natural soil and plant systems. Increasing carbon sequestration on croplands and grazing lands can reduce the rate of increasing carbon dioxide concentration of the atmosphere and help lessen the potential for global warming and other effects of climate change caused by its greenhouse effect. Sequestering and storing carbon in soil also has numerous production, conservation, and environmental benefits. Soils with greater carbon content have benefits for the overall quality of soil (through improved physical structure and retention of water, nutrients, and agricultural chemicals), water (through lessened inputs of eroded sediments and agricultural chemicals), and air (through lessened wind erosion). Interest in this topic is increasing because of the possibility for farmers, foresters, and other land mangers to receive carbon credits or payments for using management practices that could increase the amount of carbon stored in soil.

Over 60 ARS scientists at 30 locations across the United States are conducting a coordinated project called Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet) to provide information on soil carbon

status and greenhouse gas emission of current agricultural practices. The GRACEnet project has identified four products, which represent an integration of its objectives:

Product 1. A national database of greenhouse gas (GHG) flux and carbon (C) storage. All relevant project data from every network unit will be entered into a common data base for use by project scientists and potential users.
Product 2. Regional and national guidelines of management practices (in the form of a decision aid) that reduce GHG intensity, applicable for use by producers, federal and state agencies, and C brokers. These guidelines will be produced in consultation with the USDA Global Change office and others to insure that they are in a format to meet their needs.
Product 3. Development and evaluation of computer models created to assess management effects on net GHG emission. GRACEnet data will be used to evaluate the adequacy of Intergovernmental Panel on Climate Change (IPCC) emission factors and models such as CQESTR, Century, Daycent, and COMET.
Product 4. Summary papers for action agencies and policy makers, based on the current state of knowledge. The information generated by GRACEnet will be used to produce synthesis documents for action agencies such as NRCS, the USDA Global Change Program Office and other policy makers. These documents will address the feasibility of adopting the practices studied in GRACEnet and the amount of C sequestration and GHG reduction that is likely to result from their adoption as well as other issues of concern to them.

The GRACEnet work plan, milestones and products were finalized during a planning workshop held at Fort Collins during October, 2005. Since then 24 peer-reviewed journals and other (proceedings, book chapters, or abstracts) and an additional 5 popular press articles about GRACEnet and GRACEnet related activities have been published. This network of research locations, works together to better characterize management practices that would limit greenhouse gas emissions from agriculture. Information from this network approach will benefit policy makers, farmers, and the nation at-large by maintaining a food production system that has less impact on the global atmosphere. This research also contributes directly to the ARS Global Change Program National Program Trace Gases Component and contributes to the Soil Resource Management National Program (NP-202) Soil Carbon Component.

Credible, regionally-relevant data documenting agroecosystem effects on soil carbon storage are needed for successful implementation of market-based carbon trading programs. Information from a recent GRACEnet review article was used in the development of a carbon credit program for the North Dakota Farmers Union (NDFU) in collaboration with the Chicago Climate Exchange. Producers participating in this carbon credit program, which included continuous conservation tillage (no-till) and seeded grassland that are credited with 0.4 metric tons carbon dioxide/acre/year for no-till and 0.75 metric tons carbon dioxide/acre/year for seeded grass over the duration of a five year contract;

about 830,000 acres were enrolled during the 2006 sign-up period. The NDFU carbon credit program has the potential to realize multiple benefits for agricultural producers, including increased farm income and improvements in soil quality, while concurrently mitigating agriculture's impact on global climate change.

Past agricultural management practices have contributed to the loss of soil organic carbon and emission of greenhouse gases. Conservation-oriented agricultural management systems can be, and have been, developed to sequester soil organic carbon, improve soil quality, and increase crop productivity. Research collaboration between Auburn University and the USDA-ARS in Watkinsville, Georgia resulted in a document that (1) reviews available literature related to soil organic carbon sequestration in cotton production systems, (2) recommends best management practices to sequester soil organic carbon, and (3) outlines potential scenarios and future probabilities for cotton producers to benefit from soil organic carbon sequestration. Conservation tillage, cropping system intensification, sod-based crop rotations, and judicious use of fertilizers and herbicides were some of the agricultural practices found to be successful in increasing soil organic carbon. Participation in the Conservation Security Program could lead to government payments of up to $8/acre, while open-market trading of carbon credits would appear to yield less than $1/acre, although these credit amounts would likely increase should a policy to limit greenhouse gas emissions be adopted.

These and other on-going research projects being conducted under the ARS Global Change National Program Carbon and Carbon Cycle Component are increasing our knowledge base on soil carbon storage and sequestration. The basis for carbon credit trading will expand as the knowledge base grows and as this knowledge is used in cases similar to the NDFU example.

Agricultural Ecosystems

The most apparent evidence of global climate change has been changes of precipitation and temperature patterns. These changes are the result of increasing concentrations of greenhouse gases that affect the energy balance of the Earth. Not as well publicized are the effects of increased atmospheric carbon dioxide concentrations on plant growth: greater atmospheric carbon dioxide concentration has an enhanced fertilization effect on plant growth. Although this can translate to greater crop yields for some crops, it also translates to greater pressure from weeds and invasive species. Coupling changes of atmospheric carbon dioxide with changes of precipitation and temperature translates to habitat changes for pests and diseases, thus altering agricultural ecosystems.

The focus of research on this component of the Global Change National Program is to provide the knowledge necessary to assess the impacts of global change on agricultural ecosystems, and to develop successful strategies and practices to

adapt to change and/or mitigate its impact towards maintaining and improving agricultural productivity.

For example, ARS researchers from the Crop Systems and Global Change Laboratory in Beltsville, Maryland found that weed response to increasing atmospheric carbon dioxide may result in accumulation of certain biochemicals that can have adverse impacts on human health. They analyzed poison ivy plants grown under increased atmospheric carbon dioxide concentration and found that the chemicals (urushiols) are becoming more bioactive in response to rising carbon dioxide concentration. A similar study showed that the percentage of ragweed pollen protein associated with allergenicity (hay fever) increases in response to carbon dioxide concentration. These two studies indicate mechanisms by which ecosystem responses of weeds to climate change may have direct impacts on human health, especially agricultural workers spending significant amounts of time outdoors.

Increased atmospheric carbon dioxide concentration has been shown to enhance carbon supply in the above ground (shoot) plant components of wheat. However, the interaction of the effects of water stress and nitrogen under elevated carbon dioxide conditions are unknown. Research by ARS scientists at the U.S. Arid Land Agricultural Research Center in Maricopa, Arizona showed that elevated carbon dioxide and ample water and nitrogen (N) increased root and shoot mass by 18% and 16% respectively. Under drought conditions, elevated atmospheric carbon dioxide caused an increase of the exploration of roots into deeper soil layers, whereas under N deficits it induced root growth more so in the upper soil layers. The results from theses studies will enhance our ability to adapt wheat crop production management to increasing atmospheric carbon dioxide by better managing water and N resources.

Plant response to rising atmospheric carbon dioxide may affect competition from weeds commonly encountered in production crops and for invasive species encountered on uncultivated landscapes. Research by ARS scientists from the Crop Systems and Global Change Laboratory in Beltsville, Maryland indicates that growth and combustability of cheatgrass, an invasive species associated with the outbreak of fires in the Western United States, may be related to increases of atmospheric carbon dioxide that occurred during the 20th century. This study indicates that changes of atmospheric carbon dioxide may be a factor in the spread of invasive species in addition to changes of precipitation and temperature patterns.

The primary concern of global change has centered on the rapid increase in atmospheric concentrations of primary greenhouse gases such as carbon dioxide, methane and nitrous oxide since the Industrial Revolution in the latter part of the 19th century. A state-of-the-state report on global change in rangelands and pasturelands indicates that three significant advances have been made regarding plant and soil responses to increasing atmospheric carbon

dioxide and land management practices to mitigate adverse impacts of global change: 1) elevated carbon dioxide levels can significantly impact rangeland plant community dynamics, increase water use efficiency and reduce nitrogen content of the plant material; 2) land management practices, such as grazing, fertilization, fire, and introduction of legumes and improved grass species can increase soil organic carbon storage in rangelands and pasturelands; and 3) the development of non-interference methods offers promise to monitor methane emission from isolated animals to large feedlots.

Agroecosystems are complex, and thus understanding the impact of global change on system components will better enable agriculture to develop strategies to adapt and/or mitigate the impacts of global change. The research findings from ARS researchers across the U.S. studying agroecosystems will be used to develop optimal strategies that balance economic, environmental and social concerns of the 21st century.

Trace Gases

Agriculture systems emit other greenhouse gases other than carbon dioxide to the atmosphere. These trace gases include nitrous oxides and methane, both of which together have greenhouse warming potential (GWP) greater than carbon dioxide. The mission of this research component is to develop management practices to reduce trace gas emissions from cropping and animal production systems.

Trace gas studies are also an element of GRACEnet. Standardized measurement protocols are being followed by ARS researchers at different locations to measure trace gas emissions from agricultural systems. Recent results suggest nitrous oxide emissions from corn and soybean crops may be underestimated. Measurement of the exchanges of greenhouse gases such as nitrous oxide between the soil and atmosphere are key components of assessments of the effects of farming practices on global climate. Nitrous oxide emissions were measured from corn-soybean systems with full-width tillage, no-till, and no-till with rye winter cover crop for two years by ARS scientists from the Air Quality and Agricultural Systems Research Laboratory in Ames, Iowa. There were no significant tillage or cover crop effects on nitrous oxide emission observed. However, comparison of the measurement results with estimates calculated using the Intergovernmental Panel on Climate Change (IPCC) default emission factor indicated that the estimated fluxes underestimate the measured emissions by a factor of 3.0 at the Iowa sites. This study indicates that world-wide assessments of nitrous oxide greenhouse gas emissions may be seriously underestimated and requires a reassessment of the impact of nitrous oxides from agriculture on global climate.

The studies conducted by ARS scientists across the U.S. will develop the basic knowledge base on trace gas emissions from agriculture under different cropping

and management systems. By studying these emissions as a function of cropping system and management practices, new cultivation strategies will be developed to lessen the emission of these gases while maintaining/improving agricultural productivity.

Changes in Weather and the Water Cycle at Farm, Ranch, and Regional Scales.

General circulation models (GCMs) used to simulate climate responses to rising greenhouse gas concentrations indicate changes of temperature and precipitation that will vary regionally. Some GCMs also predict that weather variability will increase with global warming, introducing yet more uncertainty and risk into agricultural production. Droughts, floods, storms, and periods of excessive heat or cold may occur more frequently, with impacts on agricultural operations, alterations to agricultural water supplies, and increased crop insurance costs and disaster payments. Much of the research required to address these issues involves projection of climate and weather changes through models at many different spatial scales, which requires special attention to improve the predictive capability that will enable decision makers to manage the associated risks with minimum adverse impacts on U.S. agriculture and economy.

The mission of the research for this component is to develop management strategies for farm, ranch, rural community, and natural resource decision-makers to conserve, store, and allocate water resources to address the many diverse demands and impacts on the Nation's rural water resources that may be caused by global change. Research on other global change-related drought issues are conducted and reported as part of the Water Resources Management NP201 program.

Climate variations can greatly affect the productivity of winter wheat-grazing operations of the Southern Great Plains. A climate impact assessment tool is needed to evaluate planning and management alternatives in terms of forecasted climate conditions. A new grazing-cattle growth model was developed and incorporated into a commercial wheat production model for this purpose. Use of the wheat production and grazing model provides the means to plan and manage the wheat-grazing system under anticipated climate variations and will help mitigate adverse impacts and/or adapt to changing global climate conditions.

Approaches such as this for agricultural adaptation to climate change illustrate how climate tools must be integrated into the day-to-day decision making of agricultural operations. Decision support tools that incorporate global change-related elements (precipitation and temperature changes, enhanced atmospheric carbon dioxide, trace gas emission as a function of cropping system, etc.), and that address multiple aspects of farm and ranch operations are expected to be

able to address the changing environment that agriculture of the future may experience.

Synthesis and Integration of Research Findings

Global Climate Change issues of 1) understanding the impact of climate change on agriculture, 2) adaptation of agriculture to climate change, and 3) mitigation of the impacts of agriculture on factors causing climate change emphasizing GHG emissions, are common components adopted by USDA global change programs. Adaptation and mitigation are emerging as priorities for USDA agencies. The altered conditions under which production must proceed, with emphasis on implications for management practices that producers must adopt, and the potential effects on soil, water and air resources are major concerns. Bioenergy and carbon trading are seen as opportunities for agriculture to both reduce GHG emissions and strengthen rural economies. Market-based incentives such as integration of carbon sequestration into Conservation Reserve Programs are considered promising mechanisms for developing carbon trading programs. However, direct quantifications of sequestered carbon and the effectiveness of management procedures on GHG emissions are critical needs.

Global change research activities sponsored by ARS and other USDA agencies contribute to the U.S. Global Change Research Program (USGCRP) and the U.S. Climate Change Science Program (CCSP). The CCSP Strategic Plan calls for the creation of a series of more than 20 synthesis and assessment reports. The USDA is responsible for leading the production of Synthesis and Assessment Product 4.3 focused on the Effects of Climate Change on Agriculture, Biodiversity, Land and Water Resources. ARS scientists are providing leadership and co-authorship for this report.

ARS Global Change Research Program Cycle and Future Status

ARS National Program Research is conducted on five-year cycles. The Global Change National Program will be entering the final year of this cycle during 2007. During 2007 an accomplishment report will be assembled for the Global Change National Program and assessed by a review panel composed of non-ARS scientists as per requirements set forth by the ARS Office of Scientific Quality Review (OSQR). This cumulative report will be posted as the Global Change National Program progress report for 2007 activities. During 2008, a workshop will be convened to set the directions for the next cycle of ARS Global Change research. Starting in 2007, the Global Change National Program will be integrated with the Air and Soil Resources Management National Program (NP212) together with the Air Quality and Soil Resources National Programs. Research progress for global change topics in future years will be reported as part of the Air and Soil Resources Management National Program (NP212).