USDA Climate Change Science Plan

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Preface

Vision

Farmers, foresters, ranchers, land owners, resource managers, policy-makers, and Federal agencies are empowered with science-based knowledge to manage the risks, challenges, and opportunities of climate change and positioned to reduce emissions of atmospheric greenhouse gases and enhance carbon sequestration.

Overview

The U.S. Department of Agriculture (USDA) Climate Change Science Plan (the Science Plan) provides a guide for the Department and its stakeholders to enable clear and consistent consideration of current and potential investments in climate change science activities. This Science Plan presents an overview of the critical questions facing the Department's agencies as they relate to climate change and offers a framework for assessing priorities to ensure consistency with USDA's role in the Federal Government's broader U.S. Global Change Research Program (USGCRP) and related efforts. This document identifies important roles and responsibilities for USDA agencies and areas of needs and dependencies wherein USDA agencies are reliant on other programs for cooperation.

The vision articulated by USDA for FY 2010-2015[1] calls for the Department "to expand economic opportunity through innovation, helping rural America thrive; to promote agriculture production sustainability that better nourishes Americans while also helping to feed others throughout the world; and to preserve and conserve our Nation's natural resources through restored forests, improved watersheds, and healthy private working lands." Climate change has the potential to disrupt USDA efforts to meet these core obligations and responsibilities to the Nation.

USDA's Strategic Plan specifically addresses the challenges of climate change and the opportunities associated with addressing greenhouse gas emissions (see text box below labeled "USDA Strategic Plan"). The USDA Strategic Plan further calls on the Department to lead efforts to mitigate and adapt to climate change. The plan calls for the Department to capitalize on opportunities presented by the Nation's efforts to develop markets for ecosystem services and mitigate climate change. The Plan's second strategic goal is to ensure that our national forests and private working lands are conserved, restored, and made more resilient to climate change.

[1] USDA Strategic Plan for FY 2010-2015. http://www.ocfo.usda.gov/usdasp/sp2010/sp2010.pdf.

USDA Strategic Plan

Climate change is a central consideration in USDA's strategic planning. Strategic Goal 2 of USDA's Strategic Plan is to Ensure Our National Forests and Private Working Lands Are Conserved, Restored, and Made More Resilient to Climate Change, While Enhancing Our Water Resources. Its objectives include the restoration and conservation of the Nation's forests, farms, ranches, and grasslands; leading efforts to mitigate and adapt to climate change; protecting and enhancing America's water resources; and reducing risk from catastrophic wildfire and restore fire to its appropriate place on the landscape and are addressed throughout the Science Plan, often through multiple approaches. The USDA Strategic Plan also calls on agencies to assist rural communities by ensuring that opportunities are developed to capitalize on the Nation's efforts to develop markets for ecosystem services and mitigate climate change. This Science Plan outlines technical, economic, and communications expectations for the Department that will support this strategic objective.

USDA is unique among many Federal Departments in the broad spectrum of its agency missions, including research, applications and technology transfer, public land management, technical assistance, and communications and delivery. These missions revolve around people and land—private and public owners, rural and urban communities, fish and wildlife habitat, forestlands, croplands, grasslands, wetlands, agro-forest ecosystems, and agricultural and forest products. USDA agencies will draw upon this diversity of expertise and missions to collaboratively define and review climate change priority activities and progress towards achieving the elements of this Science Plan. Further, the Science Plan outlines linkages between USDA agencies to ensure that research results are made available to its customers, stakeholders, and collaborators using the full range of Departmental resources.

The issue of climate change is complex and affects multiple USDA mission areas and agencies. Several agencies within the Department have a role conducting research and supporting climate change science. These agencies include all of the agencies within the Research Education, and Economics Mission Area – Agricultural Research Service (ARS), Economic Research Service (ERS), National Agricultural Statistics Service (NASS), and National Institute of Food and Agriculture (NIFA). The Forest Service also has a significant research program on climate change. Each of these agencies will prepare a Climate Change Science Implementation Plan that will include specific performance measures and will build on the elements and priorities outlined in this document.

Other USDA agencies are important clients for climate change research. These agencies include: the Agricultural Marketing Service (AMS), Animal and Plant Health Inspection Service (APHIS), Climate Change Program Office (CCPO), Farm Service Agency (FSA), Foreign Agricultural Service (FAS), Forest Service (FS), Natural Resources Conservation Service (NRCS), Risk Management Agency (RMA), and Rural Development (RD).

As an active member of the USGCRP, USDA can leverage the work of the twelve other Federal USGCRP agencies and departments. The USGCRP has recently begun a strategic planning process that will determine the overall direction of Federal Government expenditures on climate change science; the USDA is actively involved in that process. Additional opportunities for collaborative work with other agencies and departments include joint

solicitations, informal collaboration and data sharing, and the Regional Climate Adaptation Consortia – called for in the recently released Progress Report of the Interagency Climate Change Adaptation Task Force.

Background

Patterns of land use, agriculture, forestry, and grazing land management in the United States and globally are shaped by and contribute to climate. There is strong scientific evidence that human-induced climate change is occurring and that these changes will continue. The Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) states "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."[2] The Climate Change Impacts in the U.S. report found that the "U.S. average temperature has risen more than 2^0F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heat-trapping gasses emitted globally and how sensitive the climate is to those emissions."[3] Similarly, the USGSRP's Synthesis and Assessment Product 4.3[4] (SAP 4.3), "The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States," summarizes evidence that global climate is changing, with increasing overall temperatures, increasing carbon dioxide (CO_2) and other greenhouse gases, and altered patterns of precipitation. As the climate changes, those responsible for managing land and water resources will need new information to help with their decision-making. For example, producers will need information to guide them on what to plant, when to plant, and what management strategies to employ during the growing season. Foresters, farmers, and ranchers will need information for management of risks posed by pests and fire. Water resource managers will need information for allocation of water resources between the demands of urban and rural populations, industry, biofuels, agriculture, and ecosystem services. USDA policymakers will need information to guide them in implementing or retooling programs impacting or impacted by climate change. At all levels, global food production data and projections will be necessary for anticipating large-scale socioeconomic feedbacks into U.S. production systems.

Globally, human activities, including fossil fuel use, land cover conversion, cement manufacture, and agricultural practices contribute to the accumulation of atmospheric carbon dioxide (CO_2) and other greenhouse gases (GHGs). It is estimated that more than one-half of the Earth's land surface has been altered during the past two centuries. During the past 150 years, land use and land use change were responsible for one-third of all human emissions of CO_2.[4]

Unlike emissions from fossil fuel use, the contributions of CO_2 to the atmosphere from land use activities are potentially reversible. Selected management practices show promise for restoration of terrestrial carbon storage. The dominant drivers of land use emissions of carbon are the conversion of forest and

[2] IPCC 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

[3] USGCRP 2009: Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

[4] IPCC, 2007: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

grassland to cropland and pasture, the depletion of soil carbon through tillage, wetland ecosystem disturbance, and other land management practices, as well as catastrophic disturbances such as wildland fires and hurricanes.

Land use practices such as livestock grazing, some manure management practices, and soil fertilization also affect emissions of other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O). Improved agricultural and land management practices can have a potentially significant role in addressing the atmospheric build-up of these GHGs over the next century.

Agriculture and forestry have a wide variety of production and land management practices that can lower GHG emissions and/or increase the quantity of carbon stored in soils and vegetation. These include shifting cropland into trees or permanent grasses, managing existing forests to store additional carbon, adopting no-till or reduced tillage systems on a long-term basis, eliminating fallow periods, planting cover crops, changing nitrogen fertilizer management practices (including rates, application method, timing, and use of inhibitors), altering livestock feed mixes, and changing manure management practices. Agriculture and forest lands can also produce biomass energy feedstocks for liquid biofuels and renewable heat and power, displacing emissions of fossil-derived fuels.

Within the United States, agriculture is responsible for approximately 6 percent of GHG emissions.[5] Beyond U.S. borders, the links between agriculture and land management and climate change are more striking. On a global scale, agriculture is responsible for 30 percent of GHG emissions, including emissions caused by deforestation and land use change.[6] The effects of climate change on agriculture, land management, and biodiversity are likely to fall disproportionately on developing countries, and worldwide food security will influence the management and economics of U.S. systems. The 2007 IPCC Fourth Assessment Report indicates that crop yields are projected to decrease at low latitudes with further increases in temperature. For air temperature increases of more than 2 degrees C above current levels, yields at mid and high latitudes are expected to diminish, as well.

Regional Climate Change Adaptation Consortia

The White House Council on Environmental Quality Interagency Climate Change Adaptation Task Force has recommended that Federal agencies develop regional climate change adaptation consortia to harmonize the efforts of decision makers and information providers by avoiding duplication of efforts and leveraging existing capabilities. USDA will work with our Federal partners at the regional scale to consider the range of programmatic activities already underway for meeting the needs of stakeholders in each region. Regional coordination will foster collaboration on the many science and service activities emerging across Federal agencies, and will create opportunities for improving the accessibility to existing science as well as responding to evolving information needs.

[5] EPA, 2010. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008*. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html.
[6] EPA, 2006. Global Mitigation of Non-CO_2 Greenhouse Gases, EPA 430-R-06-005.

USDA Climate Change Science Elements

The overarching objective of the Science Plan is to incorporate the management of climate change challenges and opportunities into the scientific missions of the U.S. Department of Agriculture. USDA has identified four priority elements concerning climate change. These elements encompass concerns and information requirements identified by USDA agency representatives, customers, stakeholders, and collaborators.

Element 1: Understand the direct and indirect **effects** of climate change on natural and managed ecosystems, including feedbacks to the climate system.

Element 2: Develop knowledge, institutional models, and tools to enable **adaptation** to climate change and to improve the resilience of natural and managed ecosystems.

Element 3: Develop knowledge and tools to enhance the contribution of agriculture, forestry, grasslands, wetlands, and other land management practices to **mitigate** atmospheric greenhouse gas emissions.

Element 4: Provide science-based **decision support** information and tools to USDA agencies, stakeholders and collaborators to improve decision and policy making.

Each of these elements is discussed in detail beginning on page 10 of this Science Plan.

Enabling Activities

The USDA has identified a set of enabling activities that are common themes across each of the four elements: assessments; data and observations; analysis and modeling; and communication, outreach and education. Focusing on these themes will help foster collaboration among USDA agencies and further enhance the service functions of USDA climate change activities to the Nation.

Assessments and Greenhouse Gas Inventories. Scientific syntheses and assessments, such as SAP 4.3 and the U.S. Agriculture and Forestry Greenhouse Gas Inventory 1990-2005[7], are examples of assessments that were produced with multiple USDA agency and collaborator contributions. USDA agencies will collectively address future requirements for these types of assessments and for broader climate change assessments. Such integrative studies will provide information needed for policy development, environmental credit trading, and educational outreach to farmers, foresters, ranchers, resource managers, policy-makers, educators, and the public. Looking to the future, USDA will continue to have an important role in assessing climate change at the national and international scales. USDA has an important role to play in quantifying GHG emissions and sinks at national, regional, and entity scales. USDA agencies will place priority on departmental and agency contributions to assessments performed for the USGCRP, the IPCC, and other relevant scientific reports, particularly those which may be expected to form the basis for USGCRP or IPCC

[7] U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. Global Change Program Office, Office of the Chief Economist, U.S. Department of Agriculture. Technical Bulletin No. 1921. 161 pp. August, 2008. http://www.usda.gov/oce/global_change/AFGGInventory1990_2005.htm.

assessments. USDA will also incorporate climate change into natural resource assessments, including the National Resource Assessment (NRA) conducted by the FS.

Data and observations. Observations needed to detect and quantify the impacts of climate change on agriculture, forestry, grasslands, and natural and cultural resources are the responsibility of multiple agencies, as are observations of adaptation and mitigation. Physical, biological, chemical, and economic data that can serve as climate change indicators, captured into and made available from data bases, will enhance climate change research, decision-making and education at USDA and throughout the Federal Government. USDA maintains observation systems to assess climate, resource conditions, and terrestrial carbon stocks. These systems include The National Resources Inventory (NRI); the Forest Inventory and Assessment Program (FIA); the Snowpack Telemetry (SNOTEL) network; the Soil Climate Analysis Network (SCAN); the Agricultural Resource Management Survey (ARMS); long-term data sets from ARS and FS field stations; and the Census of Agriculture.

Analysis and modeling. The analysis of data to test hypotheses and predict outcomes of climate change requires not only carefully documented, archived, and formatted data, but also a wide variety of mathematical models. Mathematical models are necessary to predict future climate changes and the quantitative responses by natural and managed populations and ecosystems. Many USDA models are already available for these purposes or can be modified to project climate impacts, such as the MAPPS carbon cycle model, the LANDSUM landscape model, and the FVS forest stand model. However, additional modeling will be needed and will become feasible as conceptual knowledge and computing capacity increases. The USDA agencies and other Federal and State agencies share many needs for projecting future biotic conditions, which must be generated by increasing attention to appropriate model development and applications, including economic models.

Communication, outreach, and education. Given the risks, challenges, and opportunities of climate change, informed decision-making and effective management of resources will be possible with a concerted effort to transfer information and technology to customers, stakeholders, and collaborators. Communication of climate change research outcomes, technologies, and policies to the broadest possible audience will require outreach by all USDA agencies to ensure that the benefits of USDA climate change activities are realized by the Nation and the international community.

Strategic Approaches

The Global Change Impacts in the United States[8] report states that:

". . .clear and compelling scientific evidence supports the case for a pronounced human influence on global climate."

As the fundamental questions about how the climate will continue to change and the extent of human influence on the climate system are being resolved, new

[8] CCSP 2008b. Scientific Assessment of the Effects of Global Change on the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. 271 pp.

questions about how to respond to, adapt to, and mitigate climate change emerge. Comments from the public on the USDA planning process focused extensively on the need to provide research at operational scales in order to support the implementation of responses. To be responsive to public demands, USDA scientific climate change efforts, including research, education, and extension, will need to ensure that there are clear pathways from research to operational support. The USDA program agencies (NRCS, FS, FSA, RD, RMA, and others) are incorporating climate change-related activities into their operational planning. As the Department moves to integrate climate change into program activities, additional key questions are being raised and new demands are being placed on the Department's agencies and programs.

Meeting these challenges from the public and from within the Department will require efficient mechanisms for soliciting input, setting priorities, carrying out research, and disseminating findings and recommendations. The scale of the challenges and the scope of the research questions will require mechanisms to ensure coordination within the Department, between the Department and other agencies and departments, and with the public and USDA stakeholders.

The appropriate USDA agencies will adopt the following strategic approaches to their scientific climate change efforts:

- Structure agency implementation plans to reflect the priorities identified in this USDA Climate Change Science Plan;

- Assess broader research portfolios to determine if questions related to climate change can be integrated into research being conducted for other purposes. This ensures that climate change questions will be integrated into relevant studies, analyses, observation systems, and research initiatives;

- Ensure that research is responsive to the needs of the public, stakeholders, USDA programs, and strategic decision-makers. USDA agencies will continue to maintain mechanisms for feedback from the public and other stakeholders;

- Evaluate agriculture and natural resource data collection and observation systems in the context of information needs for climate change science, dissemination, and programs. Options for adapting or modifying USDA observation and data systems to support the Department's climate change goals will be considered;

- Support priority research and decision-making at relevant spatial and temporal scales to meet emerging significant issues;

- Work with collaborators and research partners where appropriate to implement climate change activities. Leverage the work of other agencies and departments;

- Emphasize educational partnerships that convey climate change information to farmers, resource managers, and professionals at the local, State, regional, tribal, national, and international levels. USDA research agencies will enhance communication for collaboration between

researchers, research program managers, and the consumers of research products;

- Participate in relevant inter-agency working groups, such as those of the USGCRP and White House Council on Environmental Quality (CEQ);
- Acknowledge the efforts of agency employees who apply research and climate change considerations to interagency efforts and Departmental decision-making;
- Contribute to the intergovernmental Group on Earth Observations (GEO) and other relevant international organizations with similar goals.

Coordination with Other Agencies and Departments

Although USDA agencies play a critical role in U.S. Government climate change efforts, some critical scientific climate change questions cannot be addressed by USDA alone. USDA research is focused on climate change issues of relevance to agriculture and natural resources. USDA will encourage other agencies and departments of the USGCRP to undertake research to address key climate change questions that are relevant to agriculture, forests, and natural resource management, but that are beyond the scope of USDA research programs and capacities, or that would require additional resources. Examples include:

- Improved regional climate change forecasts at scales appropriate for research and decision making;
- Improved projections of atmospheric CO_2 and other greenhouse gas concentrations;
- Assessments of regional water availability for industrial, societal, ecological, and agricultural needs;
- Assessments of sea-level rise and threats to coastal zones, including wetland loss and aquaculture systems;
- Improved collaboration for joint funding of climate change science activities, including education, dissemination, and extension; and
- Improved and continuous satellite imagery for assessing land cover and land use change as well as hydrological changes, including wetland ecosystem disturbance.

Element 1: Effects

Understand the Direct and Indirect Effects of Climate Change on Natural and Managed Ecosystems, Including Feedbacks to the Climate System

Element: Improved understanding of the current and potential impacts of climate change, identifying the effects of future changes in precipitation, temperature, CO_2, soil moisture, soil organic matter, lengthening of the growing season, extreme conditions, and available water resources on natural and managed ecosystems in order to ensure the secure production of goods and services and enable the stewardship of natural resources.

- Identify and quantify the effects of changing precipitation, temperature, CO_2, and water availability, including interacting effects, on agricultural and forest productivity, food security, ecosystem services, water, soil, and other necessary quantities for sustainability; invasive species, weeds, pathogens, insects and other factors limiting the productivity of natural and managed ecosystems; natural disturbance regimes, including wildfires and extreme weather events; current and proposed adaptive management options; native plant and animal species; and water quality and quantity;

- Increase surveillance of pests and disease, including epidemiologic characteristics;

- Develop indicators and metrics from remote earth observations for identifying, measuring, and monitoring the effects of climate change;

- Improve models of plant and ecosystem processes that account for the impacts of global change;

- Evaluate interactions between social and economic indicators and the impacts of climate change on production, processing, storage, and delivery systems; rural communities; the agricultural workforce; and other human dimensions.

Climate Change Effects on Natural and Managed Ecosystems

Climate change affects food security, natural resources, and conservation efforts. The diversity of land cover types, land uses, and crops grown in the United States is directly linked to climatic conditions, as are the ecosystem services they provide. The driving variables for plant growth are light, soil, water, nutrients, temperature, and CO_2. Changes in vegetation also impact fish and wildlife. Livestock are dependent upon an adequate food supply, water, and temperature. Animal resources remain dependent upon sufficient high-quality food and water for optimal meat, milk, and egg production. Vulnerability to pathogens may be altered as a result of environmental conditions. Consequently, livestock and crops are impacted by climatic changes.

Quantifying the effects of temperature, precipitation, and CO_2 changes on managed and natural ecosystems requires research directed toward understanding the combined effects of these environmental factors on ecosystem responses. Innovative research strategies will be required to determine how the resilience and pest responses of different ecosystems are affected by climate change.

Development of improved simulation models for managed and natural ecosystems is critical to evaluating how systems respond to climate change. Ideally, simulation models would include hydrology, soil properties, land use, nutrient cycling, plant productivity, ecology, product quality, management practices, and other system-dependent quantities. Models that include economic feedbacks for different systems are essential to identify the range of potential outcomes in managed systems. A foundation for effective adaptation and mitigation practices requires predictive capabilities, including simulation models to quantify the combined effects of changing precipitation and water availability, increasing temperature, and increasing atmospheric CO_2 concentration on productivity and system services.

Carbon (C) provides the basic organic structure for all living organisms, and its storage and cycling in the soil is directly tied to soil health and productivity. Thus, C and CO_2 are major components of many important ecosystem services. An improved understanding of how CO_2 affects plant growth and development and the cascading effects on C and nitrogen cycling are needed to understand the effects of rising atmospheric CO_2 on ecosystem functions and cycles, including the global C cycle.

Examples of Departmental priorities include:

- Conduct research to quantify the effects of climate change on managed and natural ecosystems, and focus on ecosystem processes affected by climate change and the impacts on production and ecosystem services (such as water, C sequestration, and habitat);
- Develop models and data systems to help project the impact of climate change on agricultural and natural ecosystems;
- Develop and coordinate programs to monitor climate change impacts and help improve model development;
- Determine social and economic consequences of climate change for natural and managed ecosystems.

- Discover processes that affect invasive species, weeds, pathogens, insects, and other factors and their imposition on limits of managed and natural ecosystem productivity in order to understand how to maintain and improve food security and enhance natural resources;
- Increase surveillance of pests and diseases and determine the effects of climate stresses on vector behavior, distribution, and host susceptibility for varying breeds;
- Determine direct and indirect factors affecting food processing, storage, delivery systems, and overall future food security in order to ensure a reliable, high-quality food supply;
- Enhance our understanding of social and economic indicators relevant to production systems, rural communities, the agricultural workforce, and other human dimensions, and how these sectors are affected by climate change;
- Assemble databases within USDA that incorporate the effects of climate change in order to evaluate the impacts of climate change and the efficacy of adaptive management and mitigation practices;
- Conduct research on the effects of changing climate on wetlands and coastal ecosystems and their contributions to water quality, coastal storm surge protection, fish and wildlife habitat, and carbon sequestration;
- Conduct assessments of the potential impacts of climate scenarios on economic well-being of producers and on agricultural production and trade;
- Operate data collection networks and resource assessment programs that provide information about the current status and changes in the natural resources relative to climate change;
- Maintain and improve the USDA global agriculture production monitoring database and analysis process to ensure long-term continuity of consistent global agriculture production statistics to assess production change;
- Evaluate the magnitude of changes in foreign demand for agricultural commodities due to climate change and assess the availability and competitiveness of U.S. commodities to meet such demand.

Element 2: Adaptation

Develop Knowledge and Tools to Enable Adaptation to Climate Change and to Improve the Resilience of Natural and Managed Ecosystems

Element: Acquire knowledge and develop technologies to ameliorate the detrimental effects of climate change and to take advantage of elements of climate change that may be potentially beneficial to agriculture, forestry, rangelands, and natural resource management.

- Develop a suite of strategies that enable farmers, ranchers, and resource managers to cope with the challenges associated with drought, heat stress, excessive moisture, longer growing seasons, plant community changes, and changes in disease and pest prevalence;
- Evaluate sustainable practices for agricultural production and alternative strategies for increasing ecosystem resilience that enable the use of potentially beneficial aspects of climate change;
- Evaluate management actions that increase the resilience of forest and grassland processes, composition, and structure to better withstand the combined stresses of changing climate, pests, pollutants, and wildfire;
- Analyze economic costs and benefits of producer and market responses to changing climatic regimes, taking into account producer incentives and trade-offs across alternative responses;
- Evaluate management actions for maintenance and enhancement of ecosystem services such as water supply, fish and wildlife habitat, biodiversity, clean air, high-quality soils, carbon storage, and recreation within the context of global change;
- Develop metrics for evaluating and monitoring adaptive strategies;
- Contribute to inter-agency efforts, such as those at USGCRP and CEQ, toward successfully adapting to changes in the environmental and economic circumstances resulting from climate change.

Adapting to Climate Change

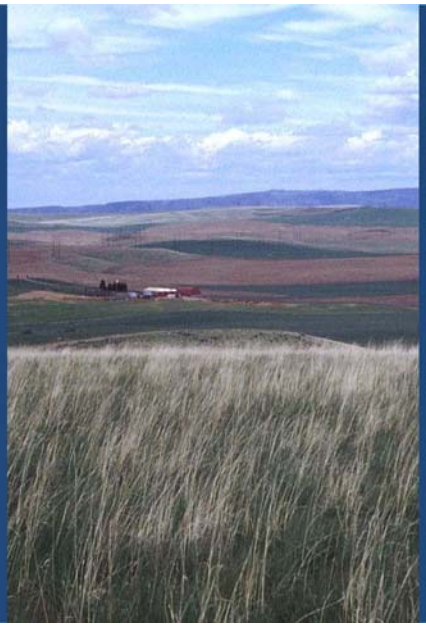
Adapting practices to respond to changing and more variable climate is necessary to address challenges to enhancing the sustainability of ecosystems and the essential goods and services they provide. Existing USDA programs attempt to introduce new technologies and practices for adaptation on the forests, grasslands and agricultural systems in the most efficient and least disruptive ways. While there may be new opportunities created by changes in local climates, adjustments will be challenging.

Mechanisms for adaptation are critical for continued commodity (food, fiber, fuel) production, conservation of natural resources, and food security. The development of knowledge and tools to enable adaptation to climate change will improve the resilience of natural and managed ecosystems. Adaptation efforts currently underway will be evaluated in order to determine potential future adaptation measures and address the related environmental, economic, and social challenges these changes present. Enhanced risk management and adaptive management strategies are key to element 2.

Examples of Departmental priorities include:

- Better understand the processes that impact ecosystem/agricultural resilience to climate change in both terrestrial and aquatic ecosystems;
- Understand both the direct effects (e.g., increasing temperature, changing precipitation, CO_2 and nitrogen fertilization) and indirect effects (e.g., interactions among plants, animals, diseases, insects, and microbes) on agricultural and natural ecosystem processes and outputs;
- Understand the tradeoffs between differing products and services under altered climate;
- Experimentally test alternative management practices and technologies;
- Monitor the effectiveness of adaptation efforts, facilitate adaptive management, and forecast potential future risks;
- Develop appropriate genetic resources for use in future climates;
- Develop improved Best Management Practices for agriculture and natural ecosystems that provide resilience and productivity given the challenges associated with drought, heat stress, moisture stress, and changes in disease and pest prevalence;
- Strengthen science-management connections (education, extension, and management input into research direction);
- Examine social and economic solutions to alter management strategies toward those more favorable under a changing climate;
- Provide information regarding sustainable operations and practices for agriculture that respond to climate change while minimizing impact on ecological or human systems;
- Disseminate materials and guidance for producers (farmers and ranchers) and managers regarding appropriate adaptive options to best optimize their operations;

- Identify strategies and practices to enable farmers and other landowners to manage for longer growing seasons, increased CO_2 concentrations, and potential productivity increases;
- Provide information regarding management actions to increase forest stress resilience focused on altering forest composition and structure to better withstand the suite of environmental stresses from changing climate, pests, pollutants, and wildfire;
- Develop strategies for accelerating adoption of sustainable production technologies;
- Devise new risk assessment and planning processes while improving existing mechanisms;
- Strengthen coordination between scientists working on climate change adaptation and other USDA programs (both financial and technical assistance);
- Analyze potential benefits, costs, and tradeoffs of options for using conservation programs, risk management tools and public investment in agricultural research and development, and genetic resources, to assist producer adaptation;
- Revise and expand existing monitoring programs, such as the FIA and the NRI, and integrate with other non-USDA monitoring networks (such as Long Term Ecological Research Program sites) to track changes in land use and management and their effects on ecosystem processes;
- Apply methods for analyzing economic costs, benefits, and feasibility of adaptation at the producer level through the macroeconomic spatial scale;
- Quantify water suppy dependence on interactions among changing landcover; atmospheric chemistry, and climate and analyze economic implications of potential producer and policy responses to changing water supply availability;
- Identify links between land use change, land use policy, and adaptation opportunities and impediments.



Element 3: Mitigation

Develop Knowledge and Tools to Enhance the Contribution of Agriculture, Forestry, Grasslands, Wetlands, and Other Land Management Practices to Mitigate Atmospheric Greenhouse Gas Emissions

Element: Resource management that reverses C losses to the atmosphere, reduces GHG emissions from agroecosystems and production systems, and increases C sequestration through research, the application of risk management paradigms, conservation planning, and program management**.**

- Evaluate management options that increase forest C sequestration by increasing the carbon stored in forest biomass and other vegetation, soils, and forest products;

- Evaluate options for biofuels and biomass for heat and power to replace fossil fuels;

- Analyze technologies and strategies for managing agricultural, forestry and grassland emissions of greenhouse gases, including CO_2, N_2O, and CH_4;

- Analyze the environmental effectiveness, economic efficiency, and tradeoffs of policy options for facilitating the incorporation of GHG management technologies into agricultural and forestry production, processing, storage, and delivery systems;

- Develop estimation and measurement capabilities for assessing the effectiveness of GHG emission and sequestration management.

Mitigating the Accumulation of Atmospheric Greenhouse Gases

Agriculture and forestry play significant roles in reducing atmospheric GHG concentrations through C storage and reduced emissions. U.S. agriculture and forestry currently offset 14 percent of overall national emissions through C storage in soils and woody biomass, and agriculture augments this number.[9] Several recent studies indicate that farm, ranch, and forest lands could increase sequestration by adjusting land uses and production systems; this additional mitigation would be highly cost-effective relative to mitigation options in other sectors.[10]

The management of N_2O and CH_4, emissions, particularly from animal production and nutrient management, is of particular importance given their potential for contributing to global warming. In addition, potential interactions between sequestered C and emission rates of GHGs must be elucidated. USDA can identify practices and opportunities to apply resource-conserving management for enhancing C sequestration in soils and vegetative matter and reducing net atmospheric GHG concentrations.

While studies indicate that forestry and agricultural mitigation measures are cost-effective relative to GHG emission mitigation options in other sectors, there are significant gaps in our knowledge that must be addressed to realize the full mitigation potential of these measures. For example, the performance of many agricultural practices for sequestering C or reducing emissions is not well known, imparting uncertainty in the long-term effectiveness and economic consequences to the producer. In a broader context, GHG mitigation is only one of a number of conservation issues facing land management, including soil and water quality, wildlife resilience and sustainability, air quality, and various other environmental services. Potential tradeoffs must be identified and evaluated in order to design effective programs, empower those who work with the land to manage the risks and challenges of changing climate, and optimize ways of addressing these challenges.

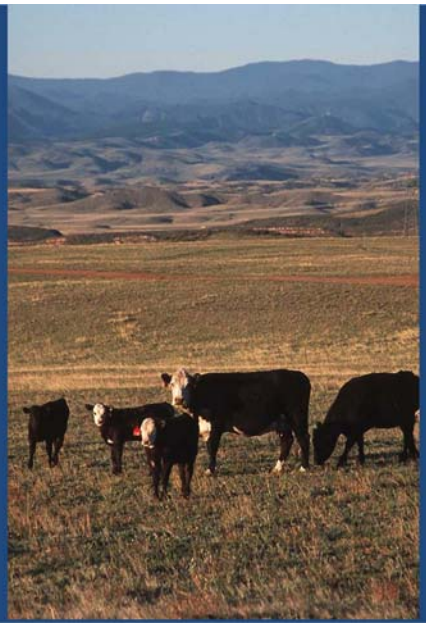
Examples of Departmental priorities include:

- Develop appropriate methodologies for measuring and estimating GHG emissions and sequestration at a variety of scales, building upon existing methodologies;
- Develop technology and management practices that will increase C sequestration
- Examine socioeconomic methods to increase sequestration.

[9] EPA 2010. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008. U.S. EPA # 430-R-10-006. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[10] For example, EPA recently evaluated several cap-and-trade policies for limiting GHG emission in the United States, which were under consideration by the 110th and 111th Congress (S. 2191; HR 2454, and S. 1733). Those analyses indicated that farm, ranch, and forest lands could increase sequestration by adjusting land uses and production systems and lower the overall cost of the program relative to a program that did not allow farm, ranch, and forest land participation (see analyses at http://www.epa.gov/climatechange/economics/economicanalyses.html). Similar findings on cost-effective mitigation efforts in the farm, ranch and forest sectors are also noted by other research groups, such as the non-partisan Congressional Budget Office. See for example, Congressional Budget Office, "The Use of Offsets to Reduce Greenhouse Gases," Economic and Budget Issue Brief (August 3, 2009).

- Develop strategies and technologies for mitigating GHG emissions and adapting/optimizing American agriculture to the changing climate, considering all relevant fluxes while improving confidence estimates;
- Improve infrastructure for maintenance of national observing and monitoring systems;
- Build stakeholder capacity for estimating, measuring, and tracking GHG emissions and C sequestration at agricultural and forestry production scales;
- Coordinate cross-agency priorities and interagency collaborations to ensure a higher return on resources invested in mitigation efforts;
- Conduct research into N_2O and CH_4 emissions and soil C-nitrogen interactions at multiple scales in agricultural and grazing lands under different management and environmental conditions;
- Improve the quantification and relative contributions of wildfires and prescribed burns to atmospheric GHG concentrations;
- Perform life-cycle analysis of production systems that quantify the response to climate variation and determine where and how production systems could be modified to meet both food security and climate change mitigation goals;
- Detail the life-cycle whole-system costs, benefits, and feasibility of mitigation options for production agriculture as well as national, state, and private forests;
- Establish technical standards and techniques for quantifying changes in GHG emissions and in C stocks from forestry and agricultural activities;
- Analyze the mitigation implications of land use and land cover change;
- Investigate potential tradeoffs related to competing Departmental conservation goals and assess possible interactions between climate policies and conservation programs;
- Analyze economic, GHG, and other environmental implications of alternative approaches to the design and implementation of GHG mitigation policies in the agriculture and forest sectors;
- Assess the contribution of biomass feedstock production for biofuels and biomass heat and power to net reductions in greenhouse gas emissions, including the impact on global land use, in coordination with the Department's research on biomass energy;



Element 4: Decision Support

Provide Science-Based Decision Support Information and Tools to USDA Agencies, Stakeholders and Collaborators to Improve Decision and Policy Making

Element: Credible, validated, and effective climate change science and technology made easily available to internal and external USDA customers and stakeholders on scales relevant to decision making.

- Provide USDA customers, stakeholders, and collaborators, including the general public, scientists, land managers, program managers, agricultural producers, and policy-makers information about climate change as it impacts agriculture and forestry;

- Integrate climate change into decision-making for management of natural and managed ecosystems using the research and development products from the three previous elements through scientific collaboration and technology transfer;

- Integrate climate change into alert systems designed to recognize developing global pest and animal disease spread patterns for protecting U.S. crops and making decisions on agricultural trade;

- Develop models, data systems, and other decision support tools to aid policymakers, program managers, agricultural producers, and land managers charged with implementing programs or mechanisms for reducing GHG emissions and enhancing C sequestration;

- Facilitate interagency communication and planning processes to ensure that research provides the relevant, timely information, and data needed by policymakers and program managers to develop or retool programs to address climate change;

- Produce synthesis and assessment products that identify climate and ecosystem responses to long-term greenhouse gas stabilization at various elevated levels; Incorporate GHG and C sequestration into USDA data collection programs and data systems.

Decision Support in a Changing Climate

The scientific research produced and funded by USDA has been used for many years to address a range of questions, from detecting climate change trends and impacts, to utilizing remote sensing, ground-based observations, and related analyses in resource management applications. The USDA will improve interactions with internal and external partners and stakeholders and develop resources to support public discussion and planning, adaptive management, and policymaking. USDA will also encourage development of new methods, models, and other resources that facilitate economic analysis and decision-making under conditions of uncertainty, and integration and interpretation of information from the natural and social sciences in particular decision contexts. This effort will include supporting and improving existing models and decision support mechanisms.

Decision-support resources can be targeted toward three broad categories: (1) monitoring, reporting, discussion, and planning based on state-of-the-science syntheses and assessments by decision makers, stakeholders, the media, and the general public; (2) operational adaptive management decisions undertaken by agricultural producers and managers of natural resources and climate services; and (3) climate change policy formulation, program development, and program implementation. Each of these categories has a unique set of stakeholders and requires different decision-support tools. However, they share a common reliance on communication between scientists and stakeholders to define the problems to be addressed, the nature of decision-support resources to be developed, the expected information to be provided, and the approach for describing levels of confidence and key uncertainties.

Development of decision-support resources cannot be isolated in a single agency or office within USDA. Success depends on developing strategies for integrating knowledge from the many diverse fields and missions of the Department and making it available within needed timeframes in usable format to internal and external stakeholders. USDA strategy for improving understanding of human-environment interactions recognizes the need for basic research regarding the natural sciences and the human dimensions of global change that will eventually produce decision-support resources.

Examples of Departmental priorities include:

- Make climate change a critical and functional component of the programmatic planning and implementation of all USDA mission areas by applying climate change science to benefit society in all areas;
- Increase public awareness of climate change science and solutions for policy and behavior change;
- Creation of trans-disciplinary research programs that include decision-support science and incorporate climate adaptive and mitigation strategies for environment and natural resource management;
- Develop innovative partnerships between Federal, States, academic, Extension Service, non-governmental, and local community organizations to create a scientifically based, socially conscious, and culturally acceptable endeavor to address climate change issues in the agricultural industry;

- Disseminate the results of USDA programs credibly and effectively and making information and products easily available to a diverse set of audiences;
- Extend models and tools developed to assess adaptation and mitigation strategies with user-friendly interfaces that facilitate decision support;
- Adopt a system science approach that includes the social sciences as an integral part of management strategies that enhance agricultural productivity and natural resource sustainability under a changing climate;
- Report climate change information from among USDA's agencies and offices in a coordinated way and integrate into existing USDA information collection programs;
- Create USDA assessment reports which address ecosystem responses to a range of changing climate patterns and atmospheric composition;
- Participate in the National Integrated Drought Information Service (NIDIS) and the proposed Climate Service under development at NOAA;
- Engage the land-grant colleges and universities for increased extension and education activities in global change and climate, including Internet-based information systems for stakeholder access to information they can use;
- Establish technical guidelines and methods to measure, verify, and report the environmental service benefits from conservation and land management activities in support of emerging environmental services markets;
- Establish a regional approach to provide climate change science information to stakeholders in coordination with land-grant universities, building on the existing USDA facilities and networks;
- Inform both public and private decision-making authorities for rural development to protect ecosystems and the environment;
- Establish a joint modeling and computing center for predicting future responses by agricultural and natural systems to changing climate and atmospheric chemistry;
- Integrate climate into alert systems which predict the spread of agricultural pests and animal diseases domestically and globally;
- Examine economic tradeoffs and cost-effective strategies for providing alternative decision support approaches;
- Assess the likely impacts of climate change on regional food security, taking into account domestic and international trade;
- Cultivate sectoral partnerships with USDA research agencies to assist with research and dissemination.

Abbreviations

ARMS	Agricultural Resource Management Survey
ARS	USDA Agricultural Research Service
C	Carbon
CCPO	USDA Climate Change Program Office
CCSP	U.S. Climate Change Science Program
CEQ	White House Council on Environmental Quality
CH_4	Methane
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
ERS	USDA Economic Research Service
FAS	USDA Foreign Agricultural Service
FIA	Forest Inventory and Assessment Program
FS	USDA Forest Service
FSA	USDA Farm Service Agency
FY	Fiscal Year
GEO	Group on Earth Observations
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
N	Nitrogen
N_2O	Nitrous Oxide
NASA	National Aeronautics and Space Administration
NEON	National Ecological Observatory Network, Inc.
NIFA	USDA National Institute of Food and Agriculture
NOAA	National Oceanic and Atmospheric Administration
NRA	National Resource Assessment
NRCS	USDA Natural Resources Conservation Service
NRI	National Resources Inventory
NSF	National Science Foundation
RD	USDA Rural Development
RMA	USDA Risk Management Agency
SCAN	Soil Climate Analysis Network
SNOTEL	Snowpack Telemetry Network
USDA	United States Department of Agriculture
USGCRP	United States Global Change Research Program