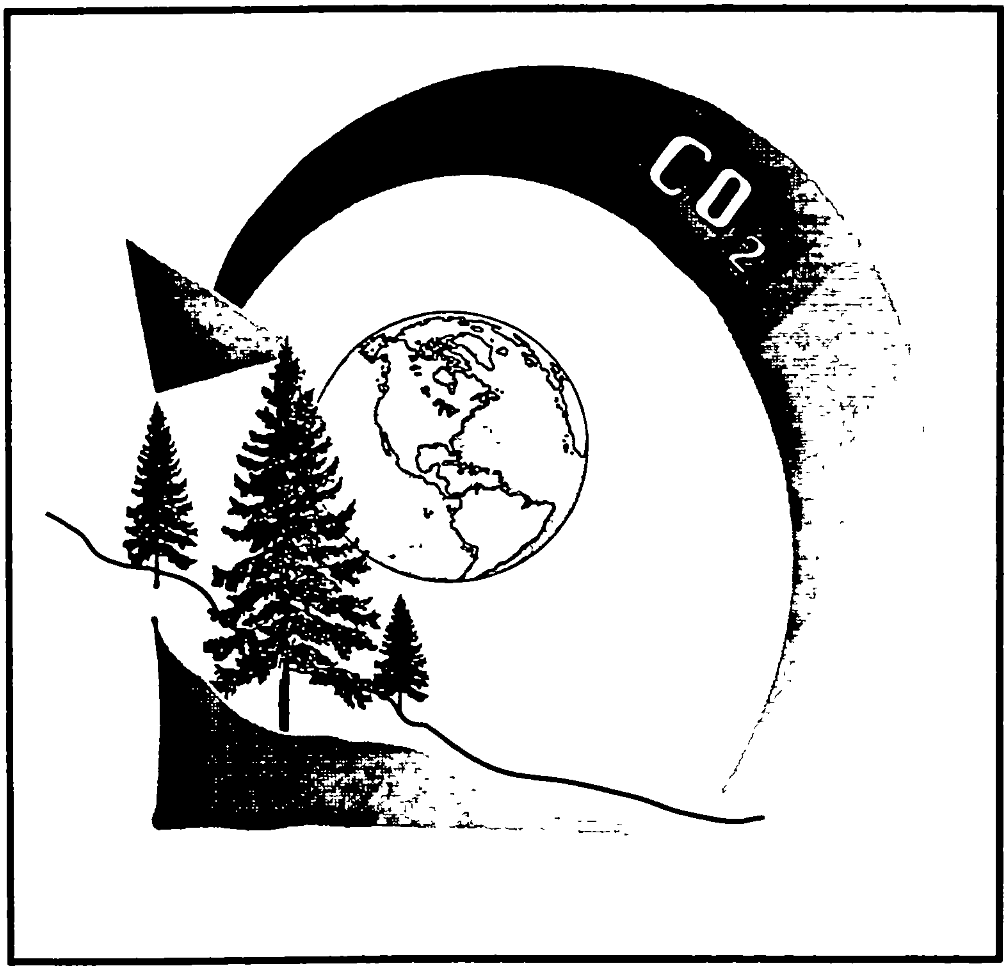
Global Change Research Program

Environmental Research Laboratory
Corvallis, OR



FY-94 & 95

GLOBAL CHANGE RESEARCH PROGRAM

U.S. Environmental Protection Agency
Office of Research and Development

GLOBAL CHANGE RESEARCH
TERRESTRIAL BIOSPHERE INTERACTIONS
Project Summaries

FY-94 & 95

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The ERL-C Research Program: Terrestrial Biosphere Interactions

The global change research at the Corvallis Environmental Research Laboratory (ERL-C) is a component of the Office of Research and Development's (ORD) national program. Research is conducted both on site, by EPA staff, university cooperators, and contractor scientists, and off site, by scientists at a number of universities and other government laboratories.

Program Goals

The Corvallis research program is focusing on:

- Predicting the response of terrestrial vegeta tion to climate change, and subsequent feedbacks to the climate system, and
- Assessing the extent to which terrestrial ecosystems, particularly forests, affect the global carbon cycle.

Overview of Ecosystem Research

The ecological uncertainties concerning global change are substantial, but the potential risks are most serious. A balanced policy demands that research be carried out now to:

- Reduce or resolve the significant scientific uncertainties regarding the effects of global climate change on natural and managed ecosystems, and
- Develop the predictive capability of pro ducing the scientific basis for cost-effective mitigation and adaptation options.

The U.S. Environmental Protection Agency has identified global change as one of its highest research priorities. The EPA Global Change Research Program (GCRP) is managed from the Office of Research and Development (ORD), and is implemented through eight EPA research laboratories.

Priority Scientific Questions

1. How much will the response of the terrestrial and near coastal biosphere amplify or dampen global climate change associated with greenhouse gases?

Currently, it is estimated that on average about 50 percent of the carbon emissions to the atmosphere is removed by sinks. For many years it was assumed that the ocean was the major sink and that the annual flux of carbon in the terrestrial biosphere was in equilibrium with the atmosphere if tropical deforestation was not considered. Today we know that global forest systems capture over 110 Gt. C annually, with decomposition and respiration contributing approximately 100 Gt. of CO_2: to the atmosphere. Net emissions from tropical deforestation and burning has been estimated to range between 1 and 2 Gt. of carbon per year.

However, uncertainties regarding the size of carbon pools and flux exist. Evidence suggests that this sink could increase or decrease in effectiveness and importance under a changing climate. A major objective of the EPA research is to provide the scientific basis for closing the carbon budget with respect to carbon flux to and from the terrestrial biosphere. Early results of the program will provide better estimates of current fluxes. Future results will allow us to account for terrestrial biofeedback in predictions of global climate change.

2. How will Climate Change Effect Important Terrestrial Ecosystems?

The rate and magnitude of change could exceed the capacity of natural systems to adapt without dramatic disruptions, and tax our ability to manage forest and agriculture systems. At the present time, our ability to predict the effects of climate change on natural ecosystems is limited in two ways. First, current climate models do not provide credible estimates of change at the regional scales necessary to link change to ecological effects. Second, we are limited in our ability to estimate ecological effects at regional and continental scales.

The EPA effects program has been designed to improve our ability to provide policy-makers with information about potential effects of climate change on the natural environment and major agricultural systems. The approach is to develop a process-based understanding of global climate change impacts and use this understanding to develop process-based models that can predict steady-state shifts in regional scale vegetation owing to climate change. Later the program will expand to address transient response of vegetation and associated ecological resources. Of particular concern are systems, including managed systems, that have been judged as vulnerable to climate change. This research will provide the scientific basis to estimate potential effects of global climate change on terrestrial ecosystems.

Research and Project Areas

The GCRP at ERL-Corvallis is organized into three research areas:

- Process and effect studies;
- Modeling; and
- Assessments.

Process and Effect Studies - This research area comprises research activity to improve our knowledge of how the global climate influences the terrestrial biosphere and how the terrestrial biosphere influences the global climate. Current and planned projects include:

- Effects of climate change on rice ecosys tems;
- Ecophysiological effects on forest tree species;
- Field studies;
- Effects on terrestrial habitat and biodiversity; and
- Interactive effects on ecological com - plexity and ecosystem functioning.

Modeling - Modeling is part of the interpretation, synthesis, and extrapolation of process studies, modeling is conceived, developed, and exercised to further our understanding and test hypotheses. The modeling area at ERL-C includes two projects:
Terrestrial systems response, vegetation redistribution, and the related water balance; and
Terrestrial systems model evaluation.

Assessments - Periodic assessments are undertaken in order to adjust the direction and focus of our efforts and to provide policy support. A series of phased ecological assessments have been developed or are planned for:

- Carbon pools and fluxes inventories for managed ecosystems including forests and agricultural systems;
- Carbon pools and fluxes inventories for managed ecosystems including forests and agricultural systems;
- Ecological effects of global climate changes; and
- International assessments.

Facilities and Expertise

The ERL-C program focus is a result of the laboratory's unique facilities and scientific expertise in the area of vegetation ecology and ecophysiology.

Experimental Facility - The Terrestrial Ecophysiological Research Area (TERA) at ERL-Corvallis is uniquely suited for the long-term study of both the above and belowground physiological responses of plants to climate change. The core of the TERA facility is an array of 12 field chambers that provide the complete climate control of an enclosed plant/soil system. Each chamber is independently regulated using individual programmable process controllers, with a central host computer system providing communication linkage with a central database manager and a site meteorology tower. Ambient weather condition and CO_2 levels are continuously monitored by the host system, and these conditions are use to derive the desired experimental treatments. The belowground chamber provides a large isolated soil reservoir which is outfitted with an array of sensors for continuous monitoring of temperature and soil moisture. Sample ports providing for the detailed study of emitted gases, soil water chemistry, and visual root observation are also built into each system. The TERA facility is ideally suited to test hypotheses concerning the response of forest trees to increased CO_2, increased temperature, and decreased soil moisture. The experiments being conducted at TERA will provide a better understanding of the effects of climate stress on above and belowground carbon dynamics, nutrient dynamics, and tree water use efficiency and evapotranspiration rates.

Spatial Analysis, Modeling and Simulation - The Environmental Research Laboratory - Corvallis has unique capabilities for performing large scale ecological modelling by virtue of its extensive Spatial Analysis, Modelling, and Simulation (SAMS) computer facility. This network provides a computing facility unique within EPA and uniquely capable for the large scale spatial modelling work outlined here. The network currently serves 75 scientists, and includes approximately 30 workstations and 40 MacIntoshes/PCs. There is in excess of 50 gigabytes of on-line storage, and a variety of laser printers, plotters, CD-ROM readers, tape drives for 3 different formats, optical read/write units, and color scanners. A fiber optics link provides direct supercomputer access. A wide variety of software including various Geographical Information Systems and image processing systems are available for spatial analysis and modelling.

Scientific Expertise - Some 25 agreements with universities and other Federal agencies are, or have been funded through the Corvallis laboratory to broaden the scope of the research and to access the best scientists throughout the world. In addition, the ERL-C program is cooperating with the International Geosphere-Biosphere Programme (IGBP) Global Change and Terrestrial Ecosystems Project (GCTE). The IGBP/GCTE provides access and coordination with research activities world wide, and provides a forum for scientific review and planing. The Corvallis, Oregon research community is among the largest cadre of forest ecology researchers in the world. The USDA Forest Service, National Park Service, Bureau of Land Management, Soil Conservation Service and EPA employ over 200 forest scientists and technicians in the Corvallis community. Many of these federal research programs focus on the role of forest systems in the global carbon cycle in support of CEES / GCRP. In addition, the College of Forestry at Oregon State University is among the most highly acclaimed forest research institutions in the world. Unique research capabilities include data bases, experimental forests and plots ranging across a gradient of precipitation, topography and soils.

Effects of Climate Change and UV-B on the Rice Ecosystem

Problem/Goal

To determine the effects of stratospheric ozone depletion and a changing global climate on the irrigated rice ecosystem.

Background

As the stratospheric ozone layer is depleted surface fluxes of ultraviolet-B (UV-B) radiation to the earth's surface are expected to increase. Concurrently, a build-up of trace gases (CO2, methane, and others) in the atmosphere is causing atmospheric warming and associated climatic change. The potential effects of increased UV-B and climate change on the world's agriculture are of great immediate concern since crop productivity must continue to increase to meet the demands of a growing human population. In addition, agricultural crops can emit greenhouse gases to the atmosphere, contributing to climate change.

Recent research has focussed on the direct impacts of climate change on potential yield from crops. However, more critical and realistic impacts of climate change will occur on complex agricultural systems including several crops as well as insects, diseases, and weeds which can substantially reduce yields.

Rice is the most important food crop in the world, supplying 21% of all calories consumed by human beings. Rice is particularly important in Asia where it supplies as much as 75% of the daily calories in countries such as Bangladesh and Myanmar. Our knowledge of the response of the rice plant to these environmental changes is quite meager. Furthermore, the net impact of the changes will depend on a balance between potential increases in yields with increased CO_2 for a C_3 species, such as rice, vs. unpredictable effects of temperature and precipitation changes. For example, crop areas could expand northward with increased temperatures, but suffer from high temperatures in other areas.

In addition, rice is unique among crops in that it is a major contributor to global emissions of methane, a critical greenhouse gas. Thus, any efforts to assess the risk to rice from climate change must also consider the impacts of climate change and mitigation strategies on methane emissions from rice fields.

Science Objectives

There will be 4 foci for specific research in this area:

1. To determine the responses of rice genotypes and important components of the rice system (diseases, insects) to UV-B radiation, increased CO2, and increased temperatures.

2. To evaluate the effects of UV-B radiation, CO2, and changing precipitation and temperature on crop yield on a regional basis in south and east Asia.

3. To determine methane emissions from rice fields and the impacts of climate change on the emissions.
4. To evaluate adaptation options can be identified to minimize negative effects of UV-B and climate on rice yields and methane emissions from rice fields.

Approach

The research is being conducted at the International Rice Research Institute (IRRI) in the Philippines, the world's center for rice research, with further collaboration with leading rice research groups in Asia, the United States and Europe. Experimental studies focus on field conditions with supporting laboratory and phytotron research. Physiological rice simulation models are being used to integrate and extrapolate experimental results to the regional level using Geographic Information Systems (GIS). This research will characterize at regional scales the risks to rice productivity from UV-B and climate change.

This program is part of a continuing research effort initiated in FY 90 and continuing for five years. Its general direction and focus responds to program-level peer reviews, and the individual projects within it are subjected to periodic peer reviews. The scientific teams are in place. Data acquisition and analyses are ongoing. Specific activities at IRRI and it's collaborators are:

UV-B EFFECTS ON RICE - Field studies on effects of UV-B on rice genotypes (tolerant and sensitive) are being carried out emphasizing phenology, morphology, growth, and yield of rice plants. Studies are being conducted during both the wet and dry cropping seasons. Phytotron (temperature and humidity controlled greenhouses) studies are focussing on the completion of cultivar screening studies and the mechanisms for differences in UV-B sensitivity among cultivars. Collaborative studies are underway with the People's Republic of China.

UV-B AND CLIMATE CHANGE EFFECTS ON DISEASE - Research models the effects of UV-B and climate change on the rice - rice blast disease system. The results from the modeling are being evaluated on a spatial basis for Asia areas using a GIS. Experiments at Washington State University are determining the direct effects of UV-B on the blast fungi itself and on fungi-rice interactions.

CO_2 AND TEMPERATURE EFFECTS ON RICE - Experiments in the IRRI Phytotron focus is on screening for the range sensitivity to increased CO_2 and temperature among domestic cultivars and wild genotypes of rice. Experiments in open-top field chambers focus on the interactive effects of CO_2, temperature, and nitrogen fertilization on rice. The emphasis is on photosynthetic responses of the rice genotypes, phenological, morphological, growth, and yield component responses

EMISSIONS OF METHANE FROM WETLAND RICE FIELDS- Studies at IRRI use an automatic sampling and analyzing system for continuous measurement of methane emissions from wetland rice fields.based on a collaborative effort with the Fraunhofer Institute for Atmospheric Research in Germany. Studies are being conducted on the effects of effects of source and manner of fertilization, and rice cultivar on methane emissions in rice fields. The effects of soil properties (pH, redox potential, electrical conductivity, texture organic matter, total nitrogen) on methane production are being studied in the laboratory for rice soils. Collaborative studies at Louisiana State University (LSU), focus on the influence of soil redoxpH conditions on methane production and methane oxidation rates using soil microcosms, the effects of soil properties on methane production rates on soils in the laboratory, and effects of organic matter, urea, and main vs. second rice crop on methane emission rates in for rice fields.

MODELING OF IMPACT OF CLIMATE CHANGE ON RICE YIELDS - Modeling activities are being carried out at IRRI and in Japan, the Republic of Korea, Peoples Republic of China, Malaysia, India, and the United States. The rice model ORYZA1 and a model from Japan are being used to estimate rice yield. Researchers are carrying out computer simulation and spatial analysis using a GIS to produce estimates of the impacts of climate change on rice yields in different agroclimatic regions of Asia.

IMPACTS OF CLIMATIC CHANGE ON RICE ECOSYSTEM - Experiments are being conducted on the impacts of climate change (increased temperature) on rice-insect interactions. Experiments evaluate impacts on insect population demographics, feeding rates, predator-prey interactions. The experiments are being conducted in the Phytotron and laboratories at IRRI with collaborative research with the People's Republic of China and Thailand. Models of insect/rice interactions are being evaluated for use in simulations of impacts of climate change on pest outbreaks for key agroclimatic regions of Asia, especially through collaborative research with the Republic of Korea.

MAJOR PRODUCTS

FY94- Annual Report on Effects of UV-B and Climate Change on Irrigated Rice Ecosystem

FY95 Assessment of impacts of UV-B radiation and climate change on the wetland rice cropping system (Proceedings of International Symposium on Rice and Climate Change in March, 1994).

FY95 Annual Report on Effects of UV-B and Climate Change on Irrigated Rice Ecosystem

FY96 Final Report on Effects of UV-B and Climate Change on Irrigated Rice Ecosystem

BUDGET ($K)

FY90	FY91	FY92
1300	1735	1550

FY93	FY94	FY95
1663	1338	500

Ecophysiological Effects of CO_2 and Climate Change

Problem/Goals

The research is focused on three major goals including:

1. What are the effects of elevated CO_2 and climate change on the growth and productivity of forest trees and soil processes?
2. Will elevated CO_2 and climate change alter the carbon sequestration potential of forest trees and forest soils?
3. What is the magnitude of elevated CO_2 and climate change impacts on forest trees and soil, and will the impacts be widely distributed?

Background

Concentrations of carbon dioxide (CO_2) and other trace gases are increasing in the Earth's atmosphere due to human activities. Evidence suggests that the increased gas levels will produce increased global temperatures and resultant changes in precipitation, cloudiness and other atmospheric factors (known collectively as "climate change"). The atmospheric changes are likely to affect all Earth processes either directly or indirectly. Of interest to future integrity of terrestrial systems and human security are the responses of forests. Understanding forest responses is crucial for resource management planning because of the long-lived nature of forests and the long lead time to realize many of the societal benefits derived from forests.

Science Objectives

Existing data do not provide scientifically defensible answers to these policy issues at the individual tree or forest stand levels. An experimental study was undertaken to contribute to the major project goals and policy issues. The experiment, which utilizes the Terrestrial Ecophysiology Research Area (TERA) of the Corvallis' Global Processes and Effects Program (GPEP), is designed to provide:

1. Determine of how CO_2 and climate change will affect forest seedling ecosystems as represented by North American Pacific Northwest forests, and
2. Assess how forest ecosystems will feed back to atmospheric trace gas chemistry.

Approach

The TERA experiment is a complex, multifaceted, highly integrated empirical effort focusing on both numerous abiotic and biotic aspects of the above- and below-ground portions of a Douglas fir seedling "ecosystem". The project is comprised of four separate but interacting research activities:

- Scoping Studies,
- Experimental Tasks,
- Modeling Tasks, and
- Integration and Inference Activities.

Current work is focused on the experimental (integrated plant and soil, and integrated above- and below-ground studies) and the iterative modeling activities. The experimental work is organized around seven tasks:

- Shoot Carbon and Water Flux,
- Shoot Growth and Phenology,
- "Ecosystem" Nutrients,
- "Ecosystem" Water,
- Litter Layer,
- Root Growth and Phenology, and
- Soil Biology.

Work will begin to include the inference and integration activities as more phenomenological data are collected.

The TERA facility is a state-of-the-science research center with the capability to investigate the effects of elevated CO_2 and climate change on plants and soils. This facility is unique compared with others because it is designed to measure and track accurately ambient CO_2, temperature and dew point while operating continuously for several years. The central component of the facility is 12 SPAR (Soil-Plant-Atmosphere Research) units, called terracosms, which utilize solar radiance and are capable of providing complete climate control of an enclosed plant/soil system.

The experimental design is a 2 x 2 factorial [two levels of CO_2 (ambient & ambient +200 ppm) and two levels of temperature (ambient & ambient +4 C)] with three replications of each treatment. The experimental treatments are defined in relation to current ambient conditions; additions to the ambient conditions are made to create the elevated treatments. The use of ambient and ambient-plus treatments insures that the experimental treatments maintain the climatic linkages.

In addition, to the treatment variables, the experiment includes Controlled Variables (levels controlled during the experiment) and Initialized Variables (levels set at the beginning of the experiment, and then allowed to vary according to treatment effects). Controlled Variables include vapor pressure deficit and soil moisture. Initialized Variables include soil nutrient pools, and soil flora and fauna.

The experiment also consists of a field study in the Oregon Cascade Mountains. Three field sites ranging in elevation from approximately 500 to 1400 m were planted to Douglas fir at the same density as in the terracosms. Selected environmental conditions are being monitored. A subset of the seedlings will be harvested annually to make comparisons with seedling growth and soil processes in the terracosms, and to calibrate the process model under development to project treatment effects on tree growth.

Major Products

- FY95 Root longevity and turnover under conditions of elevated CO_2 and temperature.
- FY96 Response of soil biological processes, populations and diversity to elevated CO_2 and temperature.
- FY97 Parameterized and calibrated tree growth model to describe effects of elevated CO_2 and temperature
- FY98 "Ecosystem" Budgets for Carbon, Water & Nitrogen.

Budget ($ K)

FY92	FY93	FY94	FY95	FY96-98
615	1000	1200	1200	1300

Habitat Sensitivity to Climate Change

Problem/Goal

The problem is to determine the potential effects of habitat modification through land use change and global climate change on animal habitats and the consequent impacts on animal populations.

Background

EPA's Science Advisory Board listed habitat modification, global climate change, and loss of biodiversity as three of the highest risk environmental problems. Habitat modification from land use changes is currently adversely affecting biodiversity and other ecological services. Climate change has the potential to compound the problem by producing additional climatic habitat modification, as well as further affecting land use. The SAB further recommended the development of tools for comparative ecological risk assessments for multiple anthropogenic stressors.

Science Objectives

1. Determine the comparative risk to a selected faunal group at the regional to continental scale from land use change habitat modification, climate change, and combined effects.

2. Determine the comparative risk to animal habitats and biodiversity for a selected landscape from land use change habitat modification, climate change, and combined effects.

Approach

A competitive Request for Proposals was issued for regional (Science Objective 1) and landscape level (Science Objective 2) comparative risk assessment studies. The choice of faunal groups, geographic areas, and methodology was left up to the investigators to propose and justify. One three year Cooperative Agreement (10/92 - 9/95) was established for each of the two types of studies.

LANDSCAPE STUDY - The University of Georgia (Ronald Pulliam, PI) was awarded the Cooperative Agreement on "Comparative Risk Assessment of Climate Change and Other Anthropogenic Stressors: Habitat and Biological Diversity on the Savannah River Site, South Carolina." The approach is to model population and community dynamics in response to climate and land use changes via their influence on habitat suitability and availability. GIS landscape mapping will be combined with a spatially explicit population dynamics simulation model that is sensitive to the distribution of habitat patches across the landscape. An existing version of this model has already been used to model the response of one particular bird species to land use changes at the Savannah River Site. The model will be generalized to allow application to a variety of vertebrate species. This generalized model will be used in a comparative risk assessment to estimate the relative impacts of climate and land use changes on a variety of vertebrate groups. The goal is to develop a general approach which could be applied to a variety of landscapes, animal species, and large-scale stressors.

REGIONAL STUDY - South Dakota State University (Carter Johnson, PI) was awarded the Cooperative Agreement on "Global Warming and Prairie Wetlands: Potential Consequences for Waterfowl". The approach is to:

- Develop hydrologic and vegetation models for temporary, seasonal, and semi-permanent wetlands;
- Assemble them into a landscape-level wetlands model;
- Project the effects of climate change and land use change on wetlands area and habitat quality by wetlands type;
- Develop remote sensing protocols to

detect changes in wetland area and condition which might indicate climate change responses; and
Relate projected changes in wetlands habitat to waterfowl population size, productivity, and species diversity.

Major Products

FY94 Manuscript on comparative risk assessment for Savannah River Site region, comparing climate change, habitat fragmentation, and land-use change as stressors on the biotic community.

FY94 Report on comparative risk assessment for effects of land use change and climate change on waterfowl in prairie wetlands.

Budget ($ K)

FY92	FY93	FY94
440	230	358.4

Field Validation - Processes/Response

Problem/Goal

The field data required to parameterize simulation models and validate model projections as well as extrapolate the results of experimental studies to larger spatial and temporal scales are lacking. For example, most forest carbon budgets have been made from forest inventories that were designed to evaluate productivity, merchantable lumber, silvicultural practices,while information on soil organic matter (SOM) generally came from broad soil surveys or were estimated. Although valuable for original assessments of carbon pools and fluxes, there is a critical need to evaluate many of those assumptions, validate the conversion concepts (tree diameter at breast height, dbh, to total forest carbon), and look carefully at the soil carbon pools and flux rates

Background

The development of field calibration and validation sets requires extensive measures of biological processes and rates. For example, the U.S. Forest Service (USFS) is involved in various studies to understand the effect of different forest management strategies on forest growth, health and wildlife habitat. One of the most ambitious is called the Long Term Ecosystem Productivity Program (LTEP). It was initiated by the USFS in the Pacific North West several years ago with the investment of over 30,000 acres dedicated for an experimental period of 200 years. This activity involves a large team of scientist who are engaged in measuring various ecological parameters and correlating them with forest growth and stability. Much of the data needed to make carbon budgets and understand the impacts of forest management on carbon pools and fluxes is contained in the data of these studies.

Objectives

The initial objectives of the research are:

1. Determine carbon pools and fluxes in forests managed to attain a variety of seral conditions. Compare the rates of carbon sequestration and retention on these sites. Particular attention to below ground processes will be part of these budgets.

2. Compare temporal patterns of carbon flux and sequestration pools under different management practices to make specific recommendations regarding forest management and harvest cycles.

3. Determine scaling factors for carbon and water fluxes in coniferous forests for extrapolating the results of experimental chamber studies to larger spatial and temporal scales.

Approach

Measured carbon fluxes will be compared with that inferred from ecological measurements and models. The USFS will use data from the LTEP to create site specific carbon budgets. Since these data were not collected specifically for this purpose, additional sampling and analysis by the USFS will be required. We will use the results to compare management practices for their impact on carbon pools and fluxes. The site specific carbon budgets will be authenticated data sets of carbon in all compartments of various forest types. All sites will be measured and evaluated in the same manner and all aspects of the measurements, sampling procedures and statistical treatment will be subjected to quality assurance evaluation. These data sets will form a basic resource for model validation. Carbon budgets will provide the information to evaluate the impact of various forest management practices on carbon sequestration and flux. This will be an important aspect of a national mitigation strategy. Corollary information regarding atmospheric, and soil conditions along with forest type will be the basis for making recommendations in support of forest management practices which foster increased carbon sequestration.

Ecophysiological measures (e.g. photosynthesis, water flux, carbon allocation, soil carbon dynamics) of plant and soil processes will be measured on forest trees of various age structure and stand conditions to develop the scaling factors required to extend experimental data from small tree studies to mature stands distributed across a landscape.

In support of AREAL's GCRP program establish gas flux measurements in a representative forest system near the ERL-C. Apply traditional ecological measurements and models to this site, and compare the carbon fluxes to the directly measured flux. Carbon flux values for Western coniferous forests will yield understanding of the effects of important meteorological parameters. Especially important are temperature and frequency and timing of precipitation. These values will allow validation of forest carbon dynamic models and the yearly patterns will allow validation of carbon budget models and also aid in the extension of experimental results to natural conditions.

This project would also support field data collection in conjunction with the EMSL-LV remote sensing program, specifically, the proposed Forest Pilot project.

Deliverables:

FY96 Report on carbon dynamics in a mature Douglas fir forest,

FY97 Report of Forest management practices on Carbon cycling.

FY98 Development of scaling factors for extending the results of EPA's TERA experiment to larger temporal and spatial scales.

Budget: ($ K)

FY94	FY95	FY96-98
600	600	1000

Global Change and Ecological Complexity

Problem/Goal

Determine the impact of global change on ecological complexity in natural and managed ecosystems, and the accompanying effects on ecosystem functioning. The research will not simply focus on responses of dominant plants (e.g. trees or crops) to environmental changes, but rather, it will address the relationships among multiple ecosystem biotic components, the effects of environmental changes on these biotic components, and how the interacting responses affect ecosystem processes such as productivity and carbon dynamics.

Background

Ecological complexity can be measured on many scales. These include the genetic diversity within species, species diversity within ecosystems, and ecosystem diversity across the landscape. Human activities have already caused significant reductions in diversity at all of these levels. Future global change, including continued human population growth, land use change, and the likelihood of global warming will exacerbate all these problems, and will likely accelerate the loss of ecological complexity. Ecological complexity is related to ecosystem functioning in ways that are only partly understood. Further understanding of these relationships at multiple scales and the ways in which rapid environmental change may affect them is critical at this stage of human development and the history of life on Earth.

The research is designed to determine the impact of global climate change on two fundamental ecological questions:

1. Does the number of species (biodiversity) "count" in system processes (e.g., nutrient retention, decomposition, production, etc) over short- and long-term time spans, and in the face of global change?
2. How is system stability and resistance affected by species diversity and how will global change affect these relationships?

SCIENCE OBJECTIVES

To assess the impact of CO_2 and climate change on ecosystem function and complexity, it is necessary to consider several scales of study. Consequently, there will be 3 foci for specific research projects in this area ranging from small scale (plot) soil/plant ecosystems to the landscape level:

1. SOIL BIOTIC COMPLEXITY - Determine the effects of altering the diversity of soil organisms on plant and soil carbon & nutrient dynamics, and the effects of CO_2, temperature, and moisture on these processes.

2. COMPLEX CROPPING SYSTEMS - Determine the effects of climate change (CO_2, temperature, moisture) on major biotic plant stresses (e.g., insects, diseases, and weeds) and the joint influence of these biotic stresses and climate change on the productivity of complex cropping systems.
3. LANDSCAPE SCALE COMPLEXITY Examine potential landscape scale responses in ecological complexity resulting from interacting effects of climate change and land use change.

APPROACH

The work will build upon current EPA research in the GCRP and related programs including work on rice ecosystems, habitat sensitivity, the TERA experimental facility, vegetation redistribution modeling, and the Biodiversity Research Consortium. Data base analyses and simulation modeling will utilize the spatial data bases and distributed computing facilities assembled in the ERL-C Spatial Analysis, Simulation, and Modeling (SAMS) facility. The proposed approaches were selected so that the EPA research would be closely linked with and support GCTE's Focus 4 "Global Change and Ecological Complexity" and Focus 3 "Global Change Impacts on Agriculture and Forestry". Experimental studies, analysis of existing geographic data bases, and simulation modeling will be used in the research.

Experimental Studies

SOIL BIOTIC COMPLEXITY - This work will build upon the existing ecophysiological research in the TERA experimental facility. An experimental approach will be taken to examine the effects of increased CO2 and temperature on plant and soil carbon & nutrient dynamics and the relationships among soil organism diversity on these processes. Three different scales of experimental systems will be utilized, representing a gradient from open canopy, open nutrient cycling tree seedling mesocosm systems, to closed canopy, closed nutrient cycling forests.

COMPLEX CROPPING SYSTEMS - This work will build upon the existing rice ecosystem research project. Experiments will be conducted on different scales of complexity ranging from a single species to multi-species systems. Single species experiments will be conducted to establish fundamental relationships among crop and pest population characteristics and climate change parameters (CO_2, temperature, moisture). Dual species experiments (e.g. insect/crop, disease/crop, and weed/crop) will obtain data for simple general models of insect feeding, disease severity, and plant competition. Complex, multi-species experiments will examine climate change impacts on crop yield, disease prevalence, and insect and weed populations as endpoints. A range of environments including controlled environment chambers, open or closed field chambers, and open FACE (Free Air CO_2 Enrichment) systems may be utilized.

Analysis of Existing Geographic Data Bases

COMPLEX CROPPING SYSTEMS - Analysis of existing biological, agricultural, and geographic data bases will be used to explore the potential for significant impacts on the geographic distribution of cropping systems and their major pests.

LANDSCAPE SCALE COMPLEXITY - The research planning process will develop specific plans for analyses of spatial data bases to examine the potential for climate and land use changes impacts on complexity at the landscape scale. For example, the Biodiversity Research Consortium (EPA, USFS, USFWS, USGS, The Nature Conservancy, and several universities) is in the process of producing integrated data bases on animal distributions and spatial patterns of suitable habitat for 6 pilot study regions, and eventually for the contiguous United States. These data bases may be analyzed using a Geographic Information System to examine the connectivity of existing suitable habitat for selected vertebrates as possible dispersal/migration corridors in response to environmental changes. Analyses may be done at several different spatial scales.

Simulation Modeling

SOIL BIOTIC COMPLEXITY - A current ERL-C research program includes the use of single tree growth models to simulate responses to climate change. The proposed work will build on this foundation and will link in soil process models and some components of the soil biota, particularly the structure and function of soil food webs.

COMPLEX CROPPING SYSTEMS - Modeling will integrate experimental results and spatial data bases to predict crop yield and pest population responses on field, landscape, and regional scales. This approach will include identification, improvement, testing, and running of models.

LANDSCAPE SCALE COMPLEXITY - Simulation modeling activities will build upon current ERL-C work examining redistribution of natural vegetation and agroecological zones in response to climate change. Possible areas for further work include the use of forest gap models to project changes in forest structure and suitability as habitat for forest animals; projecting potential range shifts of forest and agricultural pest populations in response to global change; etc.

MAJOR PRODUCTS

- FY98 Changes in production as affected by changes in insects, weed incidence and disease severity in conjunction with climate change.
- FY99 Interacting effects of climate change and soil biotic diversity on carbon and nutrient cycling.
- FY99 Animal habitat structural changes including connectivity of migration corridors in response to climate change.

BUDGET ($ K)

FY95	FY96-98
1200	1200

Processes of Ecosystem Response to Global Environmental Change

Problem/Goal

Current interest is increasing among CEES, IPCC and governmental agencies in the definition and measurement of ecological responses to global environmental change. Political action on abatement of greenhouse gas emissions is not likely to occur until scientific evidence is presented to indicate that the biosphere is responding in some functional manner to global environmental change. The development and signing of the Montreal Convention on ozone indicates that the evidence should be both conclusive and scientifically obvious. While no one ecological response will be definitive, the usual ambiguity of scientific research can be circumvented in the formation of policy, if theory can predict the emergence of an interrelated multitude of ecological changes which subsequently are measured in the field.

Background

Although no one ecological response will be definitive for change detection, this limitation can be circumvented, if ecological theory can predict the emergence of number interrelated measures of ecological changes which subsequently are measured in the field. Thus, definitive evidence of changes in ecosystem structure and functioning must be obtained at the landscape to global scale. Considering that the singularity of the earth precludes rigorous testing and scientific proof, and considering the complexity of ecosystems in combination with our sketchy knowledge of how they function, the task may seem impossible. Yet, such evidence could be obtained in a few years through (a) the careful choice for study of simple, widespread ecosystems which are themselves important in the global carbon cycle, (b) definition of a unique "fingerprint" of expected changes, and (c) judicious use of environmental monitoring which was aimed at measuring the characteristics of the fingerprint.

Detection of a fingerprint implies that the natural variation in ecosystems from one time to another has been documented well enough to distinguish it from chemical and climate changerelated variations. Hence, the challenge is to provide the definitive evidence of significant change in ecosystem functioning at a global scale, to document the difference between the changes and those resulting from natural ecosystem dynamics, and to demonstrate that the only logical source of change has been shifting atmospheric chemistry and climate.

Scientific Objectives

The primary objectives of a program designed for early or first detection of significant ecosystem response to global environmental change are to:

1. provide definitive evidence of significant, unidirectional and lasting changes in ecosystem functioning and to demonstrate that these changes are occurring globally;

2. document the differences between the measured changes and those resulting from natural ecological dynamics, or from other external forcing; and

3. demonstrate that shifts in atmospheric chemistry and/or climate provide the most complete and logical source of the changes.

Approach

The data to be collected in support of these investigations must extend throughout the globe to avoid false research trails created by regionally-unique changes. They must involve long-lived trees and forest communities in order to assure directionality and ecological significance of changes. Only perennial vegetation possesses age structures capable of predicting vegetation composition and density into future centuries. Finally, the data collection must focus on identifiable tree and forest borders where climatic gradients and thresholds control ecological dynamics, to select the least ambiguous and largest magnitude responses.

The most suitable subject of first-detection investigations is the circumpolar belt and related montane areas in which low temperatures limit tree growth. This is one of the most temperature-sensitive ecotones in the world. Absent or minimal are the intensive land uses that mask climate response and the influence of other gaseous pollutants The physiognomic contrast of forest and tundra, or montane forest and alpine vegetation, is easily recognized in remotely sensed data.

The strategy must be to hypothesize, *a priori*, a set of related ecological responses, from a set of measured environmental changes, corresponding to the criteria stated above, then to provide rigorous statistically-relevant tests of their presence. In the absence of rigorous scientific proof, the documentation of a large set of non-definitive changes (corresponding to an ecological fingerprint) can permit intelligent policy formulation based on otherwise ambiguous science.

The considerations discussed above suggest that the long-term project should be focussed on six primary subject areas:

1. Fossil pollen data (mostly extant) can be used to describe the global geography of the ecotone during the past 10,000 years.

2. Tree-ring data (also mostly extant) can be used to describe the growth patterns of the trees before and during the industrial age.

3 Remotely sensed data from aerial photography and satellite imagery should be applied to describe the detailed geography of the ecotone recently, and today.

4. Ecosystem process studies should be aimed at quantifying the spatial and temporal relationships between the ecotone and the factors which control it.

5. Mathematical modeling, based primarily on the evidence collected in parts 1-4, should be used to describe likely future responses of the ecotone, some of which will be measurable now as definitive hypothesis tests.

6. General Circulation models of the atmosphere, and available monitoring and research data, should be used to provide estimates of current and future climate to drive ecological models, and of past climate to validate ecological models.

Major Products

FY95 Major scientific meeting to define ecological fingerprint in boreal woodlands and montane treeline 94

FY99 Characterization of symptomatic eco system response to global environmental change

Budget ($ K)

FY 94	FY95	FY 96-98
400	400	400

Transient Response of Vegetation to Environmental Change

Problem/Goal

The temporal response of the terrestrial biosphere to changing climate is unlikely to keep up with the rapid temporal pattern of climate change, inducing gradually increasing lags in vegetation dynamics. The lagged ecosystem properties (slowed growth rates of individuals; loss and gain in species; declines in community density) are likely to generate irregularities in slowly changing rates of terrestrial carbon storage and release, such that the earth will behave as a source of carbon during several decades at one time, and as a sink for carbon during several decades at other times. In addition to carbon cycle irregularities, currently undocumented potential declines in biodiversity are possible as species die out in certain areas and their replacements appear there much later. The objective of the research is to understand these transient responses of vegetation communities from local to global scales and to devise, test and apply a framework for their prediction under changing climate and atmospheric chemistry.

Background

Accurate prediction of transient responses of long-lived vegetation to rapidly changing climate is critical for addressing questions of vegetation redistribution; in fact, that is the only place where our central issue of "vegetation redistribution" is addressed; the rest of the models we and others produce are either aimed at predicting "environmental changes which must force a redistribution of vegetation" or else, "vegetation which eventually could appear sometime following its redistribution". These latter approaches can generate valid estimates of the vegetation which must change or disappear with climate change, a prediction which constitutes half the concern about vegetation response to environmental change. However, they cannot predict the vegetation which will replace "climatically outmoded" communities, which constitutes the other half of the concern. Here, replacement vegetation depends on lags in migration of tree species to appropriate growth sites, and slow growth of trees to reproductive maturity. These lags, in turn, control variations in the flux of carbon between atmosphere and vegetation, generating pulses of atmospheric carbon when niches remain empty, and pulses of carbon sequestration when appropriate species become established in emptied regions.

Success in predicting transient responses of species composition, plant density, establishment, growth and mortality, can be based on processes which define transient responses in vegetation: migration of species across landscapes dissected by human uses, plant succession and delayed reproductive maturity of species, growth declines from chronic stress of continuous warming and shifts in disturbance regimes in the form of wildfire and pest/disease epidemics.

The potential for environmental change rates so rapid that species cannot migrate fast enough to fill newly-available niches indicates the need to predict migration potential. Indeed, climate change rate may be too rapid for completion of life-cycles of slower growing species, generating local extinctions of species. Predicting the magnitude of these problems demands consideration of processes defining effects of external forcing on separate life stages and understanding of the implications of interspecific competition during each life stage.

Scientific Objectives

The capability to predict carbon cycle characteristics from simultaneous temporal and spatial vegetation dynamics requires a landscape-level approach to processes which both impede and facilitate propagule transport and establishment, and which generate multi-decadal lags between establishment of seedlings and tree growth to reproductive maturity. The goal of this research is to generate a framework for assessing effects of forest succession and tree migration, to test the quantitative aspects of that framework on field data (fossil pollen evidence; current age distributions), and to apply the framework to predicting future vegetation and carbon cycle dynamics which must result from global environmental changes if the hypotheses on which the framework is based are correct. This requires, in turn, spatially distributed global data sets on current soil properties, topography, land use, climate and vegetation distributions. Spatially distributed global data sets from earlier periods of different climate are also required on soils, topography, climate and vegetation. The soils properties must be documented to define local characteristics of agricultural and wildland vegetation productivity, along with the relationships and feedbacks between vegetation productivity and hydrologic cycle elements.

Approach

The research will include field experiments and data analyses, tests of predictive frameworks and climate impact assessments from the Columbia River Watershed, the North American continent, and the global terrestrial biosphere. The hypothesized nature of transient processes will be tested by comparison of predicted tree migrations and succession with measured tree migration in the midwestern U.S. and western Europe. There, data networks describing vegetation dynamics of the past 15,000 years are dense enough to support such analyses. Additional hypotheses on current importance of transient processes will be examined by remotely-sensed and ground data collections from high latitudes under the title of "Early detection of ecological response to global environmental change." Relationships between ecological processes and climate and land use on the current landscape will be examined to determine the resulting carbon fluxes and sequestration characteristics, and, their relationship to hydrology. Statistically-defined relationships among carbon stock and flux variables will be tested by comparison of predictions to specific data collected at individual research sites.

Major Products

FY 95 Global analyses of the potential to modify current terrestrial carbon flux by changing land use pattern

FY 96 Global framework for integrating tree migration, forest succession, and landscape-level disturbances, tested at landscape scales in the midwest and Europe and linked to a global integrated assessment model

FY 98 Estimates of global carbon cycle irregularities (pulses) during the next century from transient processes, land use and climate change predictions

FY 98 Measurements of current transient response of ecosystems to global change from high latitudes

Annual Budget ($ K)

FY 94	FY 95	FY 96-98
451.2	600	900

Global Terrestrial Model Validation

Problem/Goal

Global models of biospheric change and stability are being constructed and compared to current biospheric properties to define their validity. Models which can accurately mimic today's landscapes are expected to be reliable predictors of future landscape and regional characteristics. Yet, many of the predictions diverge from one another when the several models of a given kind are constrained by conditions of a "different world" of the future. Because no more than one of a set of comparable predictions can be correct, we must assume that at least the remaining predictions (and perhaps all predictions) are incorrect One means to determine the degree of inaccuracy of separate terrestrial biosphere models is to compare model behavior under different-world conditions in which real properties of the different-world can be documented, that is, in paleoecological data of the past several thousand years. This research program is designed to generate the paleoecological data needed in model testing through such hindcasts and to test the terrestrial biosphere models being developed by EPA.

Background

Earth systems models, global integrated assessment models, and biosphere models, among others, are composed of multiple components each designed to replicate the dynamics of a specific process. Frequently, the means for testing the accuracy and validity of the individual components is obvious; the means for testing the accuracy and validity of the global model as a whole is not frequently obvious because there is only one world, the world from which the models were constructed. Like the castles and water projects drawn by the Dutch artist, M. Escher, global models can be built in which the individual model components are correctly related to one another but the model as a whole is fundamentally flawed. Such flaws may be the source of differences in model behavior already detected in *ad hoc* comparisons of biome geography, leaf area distributions and net primary or ecosystem production. Hence, wholesystem tests are required.

Most models in fact are tested on the whole system, by comparison to modern field data which has been excluded during the model design. For example, Neilson proposed developing his MAPSS leaf area model on vegetation data from the western hemisphere, and testing the model on excluded vegetation in the eastern hemisphere. Prentice and others constructed their BIOME vegetation geography model from individual, geography-free plant physiological thresholds to vegetation classes documented by Olson and others. Both the MAPSS and BIOME models generate comparably-accurate vegetation geography when compared to today's vegetation but each gives significantly different predictions of vegetation geography when constrained by the same future climate scenarios.

The only appropriate source of whole-globe data describing conditions different from those of today are in the historic and prehistoric past. The Dutch research team developing the IMAGE2 global integrated assessment model, for example, is assembling data sets on historic global changes of the past 100 years for comparison to simulated changes during that period. However, the past 100 years contains a very small amount of environmental variance compared to that expected in the natural biosphere under, e.g., doubled greenhouse gas (GHG) concentrations. The period from the Last Glacial Maximum (LGM) until the present, in contrast, contains at least the magnitude of climate change expected under doubled GHG concentrations, including an increase in CO_2 itself. The climate change since the LGM, although an order of magnitude slower than expected from GHG-induced climate change, included some 5 to 9°C of warming with a considerable intensification of the hydrological cycle. The warmth of the mid-Postglacial warm period (Hypsithermal in North

America: Climatic Optimum in Europe) was some 1 to 2°C above current global temperatures. This research project will focus on the period of about 21,000 years since the LGM.

Scientific Objectives

The validation of global terrestrial biosphere models with Quaternary (ice age) paleoecological data will concentrate on documenting vegetation reconstructed primarily from the ubiquitous fossil pollen evidence. Data from the more irregularly-available plant macrofossil evidence will be used only for specific research tasks, such as identifying local plant genera and species represented among otherwise indistinguishable pollen. The "proxy" data needs this project will fill include assessing the validity of static vegetation geography models, particularly in their ability to reproduce the ecosystem geography, taxonomic composition, and density of global LGM and Hypsithermal landscapes. The proxy data will also be assembled to test EPA transient vegetation models, especially in their ability to replicate the temporal sequences of species migration during the past 10,000 years documented in the Michigan peninsulas, in Northwest Europe, and elsewhere.

It is important to note that there are no direct measurements of the ecosystem composition, leaf area density or productivity data which models replicate. Instead, there are only temporal sequences of e.g., fossil pollen accumulation and/or composition, combined with empirical relationships developed on the modern landscape between fossil pollen and the biotic variables. Hence, a considerable portion of the research effort will be aimed at evaluating the accuracy of the empirical relation ships on which the proxy data are based.

Approach

The EPA will use a combination of in-house data compilations, cooperative agreements with universities, and Interagency Agreements (NOAA & USGS) to assemble globallycomprehensive vegetation reconstructions which are compared to specific outputs of static and transient models cited above. Much of the work will comprise close communication with other groups which have similar goals. The data compilations carried out by EPA and those sponsored by EPA among other researchers will be carefully coordinated with regional efforts now underway, including those coordinated for North America by Overpeck at NOAA, Boulder, Colorado, the European and African PMIPS Project of Guoit and others, and the more broadly-based research sponsored by the PAGES Project of IGBP, coordinated by Jack Eddy in Geneva, Switzerland.

Major Products

The project will initially generate globally-comprehensive maps of vegetation properties at the LGM, the Hypsithermal, and locally concentrated maps for the Holocene based on the largest and most available literature data sets. Successive iterations will be increasingly detailed in terms of vegetation variables generated, and of geographic specificity.

- FY97 Initial map of ecosystem geography for the globe at 21,000 and 6,000 years before present, and initial tests of then-current static vegetation models.
- FY97 Application of local species mapped abundances in Michigan Peninsulas, and Northwest Europe, to testing transient models of vegetation.
- FY98 Second iteration map of ecosystem geography, leaf-area and net primary production variables for the globe at 21,000 and 6,000 years before present.

Annual Budget ($ K)

FY96-98
500

Assessment of Forest Ecosystem Management: Effects on National and Global Carbon Dynamics

Problem/Goal

Forest systems can sequester carbon at significant rates while providing needed goods and services, consequently there is a growing consensus in the international community that the influence of various forest management practices on carbon sequestration should be determined. Under the Framework Convention on Climate change, the U.S. is committed to stabilizing CO_2 emissions at the 1990 level by the year 2000. Furthermore, as a signatory, the U.S. is committed to developing a national inventory of greenhouse gases within 6 months of implementation of the Convention. Terrestrial ecosystems exchange large quantities of carbon with the atmosphere each year, they are important components of inventories and stabilization plans for several countries, including the U.S. Because forest systems can sequester carbon at significant rates, research is needed to quantify the availability of land for more intensive management practices in both developed and developing nations.

Background

Relatively few national technical assessments have been completed for forest management impacts on CO_2 emissions. This project will conduct research specific to managed forest and agroforest systems as input to the processes of negotiating international treaties on climate change and forestry. A number of preliminary analyses indicate a promising potential for managed forest and agroforest systems to offset atmospheric CO_2 increases on a global scale. In anticipation of U.S. commitments under the Framework Convention, the project entered into research on several pertinent tasks.

Science Objectives

The Forest Systems Project seeks to assess forest and agroforest management practices and technologies for their effects on global carbon dynamics.

1. Assess the potential of forest management practices to influence carbon dynamics in the boreal, temperate, and tropical forest regions of the world.

2. Assess land use trends, carbon dynamics and forest management options for nations, including the former Russia, Brazil and Mexico to inventory CO_2 emissions, particularly from changes in forest ecosystem land-use.

Approach

Objective 1:

Published data from a number of sources and countries have been compiled to develop an extensive global database on forest carbon sequestration and conservation. A consistent approach for relating forest land use to national carbon budgets for four large forest nations in boreal, tropical and temperate regions is under development. A comprehensive economic analysis of carbon storage opportunities through improved forest management is being completed. A framework for conducting a risk assessment approach to forest adaptation to climate change will be completed. Remote sensing/GIS analyses of land availability for carbon storage in Latin America under various climate and policy scenarios is underway.

Objective 2:

Past and present land cover is stratified using remote sensing technology, carbon density for each land cover class is characterized using field research and existing data. Carbon dynamics in Brazil, Russia, U.S. and Mexico are being assessed. GIS is being used to develop spatiallydistributed models to estimate the carbon budgets during the past twenty years. A field-based carbon budget for southern Mexico will be completed and used as the basis for recommending forest management policy options to impact greenhouse gas accumulation.

Major Products

FY94 The contribution of forest land use to national carbon flux: case studies in the United States, Russia, Brazil and Mexico

FY95 Global analysis of the feasibility to conserve and sequester carbon in boreal, temperate, and tropical forest systems: impact of land-use patterns

Annual Budget ($ K)

FY94	FY95
600	200

Global Integrated Assessment Models (GIAM)

Problems/Goals

The overall goal is to create a relatively simple model of the complete global system in order to assess effects of economic and ecological decision-making on atmospheric greenhouse gas (GHG) concentrations. Of necessity, the model must be simple enough to allow anomalous or surprising results to be traced to their origins within the model, for evaluation of their importance. Yet the model must be comprehensive enough to allow assessing the impact of GHGs of changes in trade policy, carbon tax schemes, and similar actions which work through linkages among the human and natural dimensions of the global environmental system. At the very least, a modeling framework is needed in which to evaluate the many policies being considered in the National Action Plan.

The fundamental problem is to predict the changes in the concentrations of greenhouse gases in the atmosphere in the future from knowledge of dynamics in, and relationships among

- Atmospheric chemistry and physics,
- Ocean biology, chemistry and physics,
- Terrestrial ecology, biophysics and biogeochemistry,
- Human population dynamics and demography,
- Resource use, supply and demand in industry, energy, forestry and agriculture, and
- World trade in these resources.

The goal is to assess the impact on this world system generated by various proposed adaptive and mitigative actions, and by no action at all.

Background

The Presidential Science advisor, John Gibbons, has requested all federal agencies doing global change research to examine the means to conduct global integrated assessments that would include estimates of future changes in climate and atmospheric chemistry, the roles of changing human populations, land use, energy and resource use, and so on. Initial work has begun on such global integrated assessment models, and at least one (the Dutch IMAGE 2.0 Model) is currently available and running on SPARC Workstations. Some models which also include all the global social and natural systems are just being initiated, such as the GCAM Model of Battelle Pacific Northwest Laboratories. Others concentrate primarily on the social systems (ESCAPE Model, University of East Anglia; PAGE Model, Carnegie-Mellon; DICE Model, Massachusetts Institute of Technology), while natural scientists are developing much more detailed global biosphere models, but in the absence of modeled control by the human systems (e.g., ESM, EPA-Athens; BATS, University of Arizona, Tucson; EVE/GENESIS, National Center for Atmospheric Research, Boulder).

The most comprehensive of the available integrated models so far includes an atmosphere which responds to GHGs in terms of climate and chemistry; oceans which take up and release carbon via surface circulation, deepwater formation and surface temperature (climate); industrial and energy-use GHG sources related to production output and demand which are framed in terms of changing population and resource utilization by differing levels of technology; and a biosphere in which geographically- realistic land use and vegetation store and release carbon, as determined by climate and agricultural demand, the latter a response to population change and the availability of arable land.

Scientific Objectives

The IMAGE2 model and in the future, the GCAM model, explicitly simulate the quantitative coupling among human activities and natural processes which normally are not considered by modelers. The result is a model which can be interrogated by changing the emissions of specific industrial sectors, by planting trees in geographically realistic locations, by reducing population in specified countries, etc. Either model will be appropriate for assessing the ecosystem and GHG implications of human activities, especially of international programs to mitigate and adapt to environmental change.

Our objectives include inserting within one of these global integrated assessment models, a much more detailed version of North America, specifically aimed at defining the role of North American energy and resource use in global GHG concentrations, and the role of the rest of the world in North American climate, atmospheric chemistry and economy. In addition, we will add global change processes operating in North America which are likely to be important in the future, but which are not now present in global-scale models in which the lowest common denominator in data quality determine the quality for the whole model. These U.S. or North American models will allow assessment of the impact on global GHG concentrations by proposed mitigation policies to be taken by the U.S., and of impacts on the U.S. of international environmental and economic policies. The implications of specific policies being suggested for inclusion in the National Action Plan will be relatively easy to assess with the "embedded" North American/Global IMAGE or GCAM model.

Approach

The North American component of a GIAM version would take its annual atmospheric and oceanic circulation estimates and CO_2 exchanges from a GIAM (IMAGE 2.0, GCAM, etc.), but would calculate new North American values for annual changes in vegetation, land use, population, energy use, industrial activity, and so on. It would also include the processes currently under study in our transient vegetation modeling work, such as the lagged responses of ecosystems to rapid climate change, such as shifting mortality and growth by trees, migration of species as a function of land use and terrain, and so on. The natural systems would be modeled by in house personnel and the social system models would be developed by external personnel through competitive RFPs.

Major Products

FY97 North American assessment model developed and hardwired into a GIAM.

FY98 An assessment of effects of changing human population and resource use upon atmospheric chemistry, climate and the biosphere.

FY99 An evaluation of proposed mitigation and adaptation strategies in the U.S. to reduce global GHGs and to simultaneously increase U.S. productivity.

Annual Budget ($ K)

FY95	FY96-98
400	400

Integrated Risk Assessment for Rice Cropping System

Problem/Goal

A changing global climate will put the productivity and sustainability of major crops at risk. To define the extent and intensity of that risk, integrated assessments are needed for key international crops so that strategies can be developed to minimize losses. Rice is the most important crop for direct human consumption, therefore, the integrated assessment will focus on rice.

Background

Global climate change due to increases in greenhouse gas emissions will have substantial impacts on terrestrial ecosystems. These changes may also impact the ability of ecosystems to further modify atmospheric concentrations of these gases. Impacts of climate change on cropping systems can have dramatic costs in terms of human food supplies with economic and social impacts. The impacts will be more severe in lesser developing countries undergoing rapid changes in urbanization and increased intensity of agriculture.

Recent research has focussed on the direct impacts of climate change on potential yield from crops. However, more critical and realistic impacts of climate change will occur on complex agricultural systems including several crops as well as insects, diseases, and weeds which can substantially reduce yields.

Rice is the most important food crop in the world, yet our knowledge of the response of the rice plant to these environmental changes is quite meager. Furthermore, the net impact of the changes will depend on a balance between potential increases in yields with increased CO_2 for a C_3 species, such as rice, vs. unpredictable effects of temperature and precipitation changes. For example, crop areas could expand northward with increased temperatures, but suffer from high temperatures in other areas.

In addition, rice is unique among crops in that it is a major contributor to global emissions of methane, a critical greenhouse gas. Thus, any efforts to assess the risk to rice from climate change must also consider the impacts of climate change and mitigation strategies on methane emissions from rice fields.

Research is being conducted at the International Rice Research Institute and collaborating groups in Asia, the United States, and Europe, on the effects of global climate change on the irrigated rice cropping system. Outputs from that research include experimental and modeling data on the effects of increases in CO_2 and temperature on rice, diseases, insects, weeds; and on methane emissions from rice fields. The research includes modeling of the impacts of climate change on potential rice yield. However, current research but does not include modeling of interactions among rice and other cropping system components which affect yield and methane emissions. Therefore an integrated assessment of the effects of climate change on the rice cropping system is needed to determine effective strategies to maintain and sustain rice yields while reducing methane emissions from rice fields.

Science Objectives

There will be 4 foci for specific research in this area:

1. to characterize current and predicted levels of CO_2 ,temperature, and precipitation in critical rice growing areas;

2. to develop a cropping system model to integrate responses of rice plants and other components of the rice system to climate change and accompanying land use change;

3. to assess the risk to rice ecosystems from climate change through the use of simulation models and a geographic information system (GIS); and

4. to assess the mitigation and adaptation options for the rice cropping system in response to climate changes.

Approach

This assessment will be carried out according to the Ecological Risk Assessment Framework proposed by the EPA's Risk Assessment Forum. The study will fall under four areas:

PROBLEM DEFINITION/SCOPING - A workshop will identify a conceptual model for the irrigated rice cropping system and evaluate available information regarding its key components. A research program will be developed which will be integrated with, and a core project of Activity 3.1 "Effects of Global Change on Key Agronomic Species" of the Global Change and Terrestrial Ecosystems (GCTE) program of the International Geosphere-Biosphere Programme (IGBP).

CHARACTERIZATION OF STRESS - General Circulation Model (GCM) outputs for key rice producing areas of Asia will be evaluated assuming different atmospheric CO_2 concentrations. The GCM projections will be used with historic and current climate data to produce estimates of temperature, precipitation, cloudiness, and wind patterns for key agroclimatic areas. These outputs will be inputs for regional analysis during risk characterization.

CHARACTERIZATION OF ECOSYSTEM EFFECTS - Data from controlled experiments (field, controlled environment, laboratory) will be evaluated to determine the range and intensity of response of key species in the irrigated rice cropping system. Crop yield, methane emissions, and insect, disease, and weed populations will be specific endpoints, but other parameters such as system carbon and nitrogen balances will also be studied.

RISK CHARACTERIZATION - Risk characterization using the outputs from stress and ecological effects characterization. Rice yields and methane emissions will be calculated for irrigated rice producing areas of Asia using a rice cropping system model. The outputs from the cropping system model will serve as inputs to GIS spatial databases. These databases will then be used to produce rice yield change estimates, methane emission, and/or other parameters on a regional basis. The risk characterization will include an evaluation of the economic costs of different strategies to maintain rice yields while reducing methane emissions. It will also include an analysis of potential shifts in land use required to maintain rice production with climate change, and the impacts of those shifts on unmanaged systems. Ultimately, assessments based on these estimates will provide options for policy makers and rice producers when they are called upon to make recommendations to mitigate the effects of global climate changes on rice.

Major Products

FY96	Cropping System Model to determine impacts of climate change on rice yields and methane emissions.
FY97	Assessment of impacts of climate change on rice yields and methane emissions.
FY98	Assessment of impacts of global climate change and land use on Asian rice production and methane emissions.
FY99	Recommendations for maintaining rice yields and reducing methane.

Budget ($ K)

FY94	FY95	FY96-98
175.8	200	400