United States
Department of
Agriculture

Forest Service

Northeastern Forest Experiment Station

General Technical Report NE-214

Proceedings

1995 Meeting of the Northern Global Change Program

NORTHERN
GLOBAL CHANGE
RESEARCH PROGRAM

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1995 Meeting of the Northern Global Change Program

March 14-16, 1995
Pittsburgh, PA

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FOREWORD

The Northern Global Change Program meeting was held March 14-16, 1995, in Pittsburgh, Pennsylvania. Its purpose was to chronicle the research activities of the Northern Global Change Program over the past five years, and outline the implications of these research results for natural resource management. We thank the authors for their participation and for promptly submitting their papers in both paper and electronic form.

THE NORTHERN GLOBAL CHANGE RESEARCH PROGRAM

Richard A. Birdsey, John L. Hom, and Marla Emery[1]

Abstract: The Forest Service goal for global change research is to establish a sound scientific basis for making regional, national, and international resource management and policy decisions in the context of global change issues. The objectives of the Northern Global Change Program (NGCP) are to understand: (1) what processes in forest ecosystems are sensitive to physical and chemical changes in the atmosphere, (2) how future physical and chemical climate changes will influence the structure, function, and productivity of forest and related ecosystems, and to what extent forest ecosystems will change in response to atmospheric changes, and (3) what are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity. The NGCP currently emphasizes scientific inquiry into the effects of multiple air pollutants and climate changes on forest ecosystems. As the program matures, the impacts of prospective changes on interactions between forest ecosystems and social and economic processes will be evaluated, as will policy options for mitigating or adapting to predicted changes.

INTRODUCTION

Global change adds a new dimension to forest management policy and practice. Historically, management planners assumed that the physical and chemical environments on which a forest ecosystem depends would remain roughly stable. Our incomplete understanding of landscape-scale processes and our inability to predict how ecosystems will be affected by future environmental changes limit effective management planning and application. Furthermore, since we cannot predict the fate of many plants and animals under changing climatic conditions, we cannot adequately evaluate the mitigation and adaptation strategies under consideration by policy makers in response to increasing atmospheric CO_2 and possible climate changes.

Forest resources in the Northeastern, North Central, and Midwestern United States are intensively utilized for many different purposes. Population density is high and people are intimately associated with forest values in the Northeast, the most densely forested region of the United States. In the North Central and Midwestern states, forests scattered throughout agricultural landscapes play an important role in reducing sediment and nutrient runoff from farmlands to aquatic ecosystems. Both large and small municipalities rely on forested watersheds for water supplies. Local communities are tied to forest resources for outdoor recreation, hunting, maple syrup production, wood fiber production, and aesthetic values. The mix of urban, agriculture, and forest cover produces a fragmented landscape that in some areas may affect the ability of tree and wildlife species to adapt to major environmental stress or to migrate along with the changing environment.

Along with climate change, air pollution and acidic deposition exert strong influences on forest ecosystems in the northern region. Gradients of moisture and temperature are supplemented by strong pollutant deposition gradients, generally from very low levels in the Midwestern plains to the highest national levels in the East. Climate and pollution stresses, and their interactions with pests, humans, and other environmental changes are likely to cause unprecedented cumulative effects on northern forest ecosystems.

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GENERAL PROGRAM DESCRIPTION

Program Goals

The Forest Service goal for global change research is to establish a sound scientific basis for making regional, national, and international resource management and policy decisions in the context of global change issues. This is accomplished through a broad research initiative addressing the three national research questions concerning global change and forest ecosystems:

1. What processes in forest ecosystems are sensitive to physical and chemical changes in the atmosphere?

2. How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems; and to what extent will forest ecosystems change in response to atmospheric changes?

3. What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity?

Answers to these research questions will provide guidance to policy makers and resource managers.

Research in the North (Figure 1) will lead to understanding of how changes in the physical and chemical environment will impact forests and people's associations with them. The challenge and opportunity facing the NGCP is to increase understanding of ecosystem processes and global change effects at various temporal and spatial scales, and to identify key processes that link temporal and spatial scales. The NGCP currently emphasizes scientific inquiry into the effects of multiple pollutants, atmospheric change, and increased climatic variability on forest ecosystems. As the Program matures the impacts of prospective changes on interactions between forest ecosystems and social and economic processes will be evaluated, as will policy options for mitigating or adapting to predicted changes.

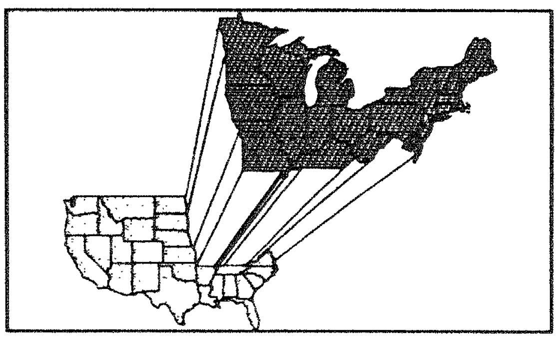

Figure 1. Regional emphasis of the Northern Global Change Program.

Program Budget

The annual budget for the NGCP has been approximately $6.5 million per year. Of this amount, approximately half is appropriated directly to field locations and half to program management for funding research studies selected through a competitive, peer-reviewed process. The operating goal is to fund 50 percent internal and 50 percent extramural research by interdisciplinary teams of federal and nonfederal scientists.

Research Emphasis - 1991 to 1993

Initial priorities focused research on the effects of global change on forest health and the productivity of forest lands. Approximately 50 percent of the research effort was a continuation of studies related to acid deposition and ozone effects, and 50 percent was allocated to study the effects of stresses identified with climate change (CO_2, temperature, precipitation, weather events). The approximate percentage of funds allocated to six broad research areas for the first three years was:

Studies of physiological processes	25%
Studies of ecosystem processes	48%
Landscape-scale studies	8%
Model development and application	15%
Social interactions and economics	2%
Assessment and policy	2%

Research Emphasis - 1994 to 1995

More recent studies increased the program emphasis on the complicated issues of species migrations and composition changes, and effects of expected changes on human interactions with forests, including model development and application to support policy assessments (regional and national) and technology transfer. As a result, funding allocations to the six research areas has shifted to the following approximate distribution:

Studies of physiological processes	20%
Studies of ecosystem processes	40%
Landscape-scale studies	10%
Model development and application	15%
Social interactions and economics	5%
Assessment and policy	10%

Specific subject areas have been identified as lacking sufficient resources to complete regional and national assessments by 1997. These subject areas may receive emphasis in new research initiatives. The relative emphasis of these and possibly other subject areas is part of an ongoing review process.

PROGRAM COMPONENTS

Monitoring and Predicting Regional Environmental Change

Information about historical climate is used in the analysis of ecological data to develop models relating ecosystem processes and responses to climate, and to develop analogs for future climate scenarios at regional to local scales. NGCP researchers have developed techniques for modeling historical and current climate at specific locations of interest to land managers, and can produce estimates of precipitation and ionic deposition at any point in the NGCP region. We have the capability to project regional climate changes by nesting a mesoscale climate model within a specific area covered by much larger scale global climate models that are unable to resolve important local features such as topography and large water bodies.

Responses of Northern Tree Species to Regional Stress

Our understanding of how and why individual trees respond to change is inadequate because multiple interacting stresses may produce responses that are considerably different from reactions to any one factor. Since controlled experiments are limited in scope to evaluation of a few factors and their interactions, we have linked carefully selected experimental studies with models of physiological mechanisms to predict the complicated tree responses more realistically. Our ongoing objective has been to conduct comparative experiments on immature and mature trees, with the eventual goal of conducting experiments at the stand or ecosystem level.

We have featured research on the effects of chronic CO_2 and ozone exposure, interacting with nutrient and moisture limitations. Key responses include changes in carbon allocation, altered ecosystem productivity, and effects on susceptibility to insect defoliation and disease. Extrapolation of these results to the ecosystem level and larger regional scales of interest to land managers and policy makers is based on mechanistic models at different scales.

A sizable body of research indicates that deposition of nitrogen and sulphur compounds via clouds, rain, snow, and wind is impacting the health of some tree species in the northeastern United States. Several NGCP studies are advancing our understanding of the affects of acid deposition on spruce physiology and cold tolerance. Additional studies examine the effects of acid deposition on ecosystems through changes in nutrient cycling.

Several long-term studies have been initiated or adopted by the NGCP to improve understanding of the physiological and genetic mechanisms of tree resistance to stresses such as physical and biological damage, disease, and water stress. An understanding of the mechanisms by which trees adapt to rapid change is critical to planning for climate change. Adaptation may be a significant alternate survival strategy to migration for some species, and will surely have an impact on future species composition, biodiversity, and the status of sensitive ecosystems.

Responses of Ecosystem Processes to Regional Stress

To successfully manage forests in a changing environment we must understand the complex dynamics of forest ecosystems as well as the responses of individual trees. Unless we have long-term records of environmental variables such as temperature, soil solution chemistry, and vegetation responses such as tree growth and mortality, we have no yardstick against which to measure our predictions about ecosystem responses to environmental change or to test the results of our models. The NGCP has continued observations at seven intensive research sites established during the National Acid Precipitation Assessment Program (NAPAP). Measurements of climate variables, atmospheric deposition, throughfall chemistry, and soil solution chemistry have been made for up to six years. Continuing such measurements over a long period of time can provide complete characterization of the variability in deposition and mineral cycling rates, and their relation to tree health.

Northern forest soils are susceptible to increases in the amount of soluble aluminum as a result of acidic deposition. Elevated concentrations of aluminum are toxic to roots and can inhibit the availability of calcium, an important nutrient. Establishing a cause-effect link between acid deposition, soil chemistry, and tree health was one of the major challenges of the NAPAP program; however, there are many factors affecting northern forest ecosystems and it became extremely challenging to establish a direct causal link. Under NGCP, research has continued on these important soil-mediated effects of acidic deposition. Several experiments have been established to study how a changing climate may affect tree growth through alterations in soil processes.

Forests in the North are dynamic and typically in a state of recovery or succession following the last disturbance, whether timber harvesting, land clearing and reversion to forest, or natural events such as hurricanes. Understanding ecosystem responses to environmental change requires a solid understanding of how disturbance impacts the processes that govern successional change. NGCP scientists are studying the impacts of harvesting and natural disturbance on microclimate, species succession, nitrogen saturation, cation depletion, and carbon dynamics.

Forest and Landscape Responses to Regional Stress and Management Activities

A significant alteration in the mix of tree species, in the productivity of forest lands, or in the health of existing forests could have a substantial impact on aesthetic and commercial values of forests, as well as wildlife populations and associated forest values. Understanding how basic forest parameters are affected by environmental change is the objective of a series of observational and modeling studies. Where possible, long-term permanent plots have been relocated and remeasured to detect changes associated with disturbance, acid deposition, and climate. These data sets are used to both explain observed vegetation characteristics, and to parameterize models so that predictions about future changes over large areas can be made.

Some tree species and ecosystems are more sensitive to climate and atmospheric chemistry than others, and are more rapidly affected by change. The susceptibility of vegetation to change, and the rate of change, will be influenced by the interaction of weather patterns and such factors as soil chemistry, elevation, and land use. Studies of vegetation history have shown that the occurrence of an individual species or a whole biome is closely related to past climate changes. It is inevitable that species distributions will shift, either from climate change or other natural and human-induced environmental changes.

Changes in disturbance patterns are likely to be one of the more striking features of a changing climate. Studies of individual disturbances and relationships to global change will eventually lead to a more comprehensive understanding of the long-term role of disturbance in shaping forest communities. At the landscape scale, the NGCP has focused disturbance research on drought and fire regimes, and the possible role of global change in patterns and intensities of these disturbances. The climate changes predicted by GCMs would also lead to altered patterns of insect infestation. To anticipate these changes and their implications for forest health and productivity, the NGCP has undertaken research on the potential effects of climate change on insect populations.

Human-Forest Interactions and Regional Change

A growing number of NGCP studies address natural resource policy issues and management in a changing environment. Estimating carbon sequestration or release for managed forest ecosystems is crucial to understanding the role of terrestrial ecosystems under changing climates. This estimation requires a reliable assessment of the quantities of carbon stored in various ecosystem components such as the plant biomass, forest floor, and soil, along with a recognition of spatial patterns of ecosystem carbon variability. Regional-scale estimates must consider patterns of carbon variability and interactions with environmental factors and land use change to accurately estimate the effects of change on forests at landscape and regional scales.

The NGCP includes a series of studies designed to quantify how carbon in forested landscapes changes over time. Attempts to quantify the role of Northern forests in the global carbon cycle, and to understand the effects of alternate management activities on carbon storage, have been hampered by a lack of quantitative information. These studies are intended to fill this knowledge gap.

An Integrated Model of the Effects of Global Change on U.S. Forests

Environmental change could be rapid relative to the ability of a species to adapt or migrate. The capability to project successional change is particularly important because rapid environmental change could induce forest health problems during a transitional change from one vegetation type to another. Significant problems with forest health would in turn affect forest resource use and the people dependent on the multiple resource values of forests, from the timber industry to the subsistence user.

NGCP scientists are participating in the development of a national integrated model of global change effects on forests. The integrated model combines submodels of the physical, biological, and social systems. Climate models at global and regional scales, and hydrologic models represent major physical systems. Several different models of ecosystem change are being developed and evaluated at different temporal and spatial scales. The human dimensions are partially captured with econometric models of the forest sector, which can project land use change, harvesting activity, and impacts of change on the forest products industry.

Development and application of the integrated model are based on models used to conduct national assessments required by the Resources Planning Act (RPA). The integrated model provides analyses of the effects of scenarios of global change on forests, and can be used as a tool for evaluating alternate policy responses to projected changes. Initial efforts are focused on improving projections of potential forest vegetation distribution, forest ecosystem composition, forest growth, and the national carbon budget. As capability to project vegetation changes improves, the modeling system will be extended to project changes in other forest system attributes such as biodiversity and wildlife habitat.

An ongoing synthesis of basic forest statistics and development of carbon accounting models has highlighted the past and prospective role of U.S. forests in the global carbon cycle and provided input to policy decisions regarding the effects of alternate strategies for offsetting greenhouse gas emissions through forestry actions. The U.S. carbon budget model (FORCARB) predicts carbon in major forest components: trees, understory vegetation, the litter layer and coarse woody debris, and soils. Although still under development, early versions of FORCARB have provided input to national decisions regarding the effects of alternate policies for offsetting greenhouse gas emissions through forestry actions. Using statistics from a nationwide inventory of trees and data from site-specific studies, the model makes continental-scale projections of the carbon that would be released and/or sequestered by various management activities that could result from national policy decisions.

Analyses at the national scale may obscure important regional changes that are likely to occur in specific ecoregions. There is a need to develop integrated models at the regional scale that are optimized for the specific domains under study -- large watersheds, river basins, multi state areas, economic regions, and the like. At the same time, there is an opportunity to establish feedbacks between national- and regional-scale models so that information developed at the national scale provides the context for regional assessments, and regional studies (that may contradict national studies) can be used to verify national-scale results or investigate possible regional effects in more detail. Model comparisons at different spatial and temporal scales are important to understanding the capabilities and limitations of models that are becoming widely used in assessments.

Boreal Forests and Global Change

Boreal forests play a major economic, social, and ecological role in the global environment. Circling the northern latitudes, boreal forests occur within the borders of Russia, Canada, the United States (Alaska), Finland, Norway, and Sweden. With an area of 920 million hectares they comprise 29 percent of the world's total forest cover. Boreal forests may be the single largest terrestrial carbon sink, with an estimated 40 billion tons of the world's stored carbon in Siberia's forests alone.

Boreal forest range and health are closely tied to prevailing climate conditions. Current projections indicate that global warming will be detected earlier and most strongly at high latitudes. NGCP scientists are part of a cooperative international effort to study boreal forests and the implications of global change for this critical ecosystem.

DELINEATION OF CLIMATE REGIONS IN THE NORTHEASTERN UNITED STATES

Arthur T. DeGaetano[1]

Climate is a primary criterion for the development, description and validation of subregional levels of the National Hierarchical Framework of Ecological Units. However, climate information is not currently available in the form or level of detail required for integration with other biophysical factors at the section or subsection levels. In this study, historical climate data from 640 observing sites in the northeastern United States and Canada are used to delineate climatic zones with sufficient detail to be incorporated into subsection levels of the National Hierarchical Framework of Ecological Units.

For each site a total of 110 climatological variables representing such parameters as monthly average temperature, temperature extremes, frost occurrence, precipitation, and potential evapotranspiration were quality controlled and adjusted to a standard observation hour. In addition, missing temperature observations were estimated to yield a serially complete temperature data set. All variables are representative of the 1961-1990 climatological normals period. Using principal component analysis, the intercorrelation of these variables is eliminated and thus the size of the original data set can be reduced. Eight components, explaining 94 percent of the variability in the original 110 variables, are retained for subsequent analysis..

Based on the retained components, Ward's method of cluster analysis is used to define 54 climate zones within the region. These zones are used as initial seeds for nonhierachical K-means clustering. This second clustering eliminates several of the shortfalls associated with hierarchical clustering and allows the grouping of stations based on a variable number of initial components.

Once this grouping of stations was established, discriminant functions were calculated to express the station grouping in terms of variables derived from latitude, longitude and elevation. Cross validation showed that more than 60 percent of the stations were correctly classified based on the discriminant functions. Since the spatial resolution of the 640 climatological stations is relatively low, a 5 minute grided elevation data set was used in conjunction with the discriminant functions to produce the final climate delineations.

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ENHANCEMENT OF REGIONAL WET DEPOSITION ESTIMATES BASED ON MODELED PRECIPITATION INPUTS

James A. Lynch[1], Jeffrey W. Grimm[2], and Edward S. Corbett[3]

Application of a variety of two-dimensional interpolation algorithms to precipitation chemistry data gathered at scattered monitoring sites for the purpose of estimating precipitation- born ionic inputs for specific points or regions have failed to produce accurate estimates. The accuracy of these estimates is particularly poor in areas of high topographic relief. Because wet deposition of pollutants is a function of both the ionic concentration of precipitation and precipitation volume and because the local distribution of precipitation can be strongly influenced by terrain, incorporation of orographic effects into the wet deposition modeling process should markedly improve the accuracy of estimated depositions. This presentation describes progress made in the development and application of a model which utilizes topographic features for the purpose of estimating wet deposition of major ions for any portion of the region encompassed by U.S. Forest Service Northern Global Change Program (NGCP).

The coordinates, elevations, and monthly precipitation records from the National Oceanic and Atmospheric Administration's (NOAA) precipitation monitoring sites in the states contained in and adjacent to the NGCP comprise the precipitation volume data set used for model development. Precipitation concentration data were derived from the weekly samples collected at National Atmospheric Deposition Project/National Trends Network monitoring sites which lie within or adjacent to the NGCP area.

Initial efforts to incorporate topographic effects into the precipitation volume component of the deposition model entailed an extension of the multi-quadric equation algorithm (MQE) to include scaled elevation as a third spatial dimension. This refinement greatly improved the ability to estimate precipitation volumes at validation points, particularly in small (one- to two-degree) regions with mountainous terrain. However, application of the 3-D MQE algorithm to an entire region as climatically and topographically diverse as the NGCP area was untenable due to the absence of a non-interactive procedure to determine the elevation scaling factor for each specific subregion. Further, the 3D-MQE was not appropriate for the incorporation of slope and aspect information. Similarly, co-kriging with topographic parameters was deemed too operator- intensive because of the changing influence of terrain on the distribution of precipitation across a large geographic region.

The present form of the precipitation volume model is a moving-neighborhood, distance- weighted, robust stepwise regression of monitoring site precipitation observations on latitudinal and longitudinal coordinates, elevation and a set of variates representing both slope and aspect. The derived regression equations from each neighborhood (0.1-degree block) are then applied to corresponding digital elevation data (DAM) to produce a grid of precipitation estimates at of the current model is assessed by comparing the predicted and observed quarterly and annual precipitation volumes at approximately 1500 validation sites scattered over the NGCP region. At this point, the average annual estimation error is consistently near 3.0 inches for each year from 1991 through 1993.

A major limitation on the accuracy of the precipitation volume model is the imprecision of the coordinates of the NOAA precipitation sites. NOAA coordinates for rain gage location are reported at a resolution no finer than 1

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minute of a degree of latitude or longitude. This level of uncertainty in the location of sampling sites impedes the modeling of localized, but important, orographic influences on precipitation. Unfortunately, NOAA data comprise the only precipitation data set that covers the NGCP area at a site density sufficient for deposition modeling. In order to scavenge some useful slope and aspect information to be used with the NOAA observations, a long-range, neighborhood-oriented expression of slope and aspect was developed and incorporated into the precipitation-volume model. This subroutine within the model could be vastly improved with more precise coordinates of each NOAA precipitation monitoring station.

Future efforts in refining the deposition model will focus on enhancing the estimates of precipitation concentrations and on refinements that will improve model performance along the region of the NGCP that borders on Canada and over large bodies of water, such as the Great Lakes. We will also obtain precipitation chemistry data from other monitoring programs, such as the Electric Power Research Institute, to use in model evaluation and verification. Application of model output to cause-effect relationships, nutrient budgets and management, and hydrologic models will also be undertaken. Examples of such are requests for quantifying atmospheric deposition of nutrients to the Chesapeake Bay, determining mean precipitation values needed for use in the hydrologic module of the Northeast Decision Model, and the calculation of atmospheric deposition loadings over the Allegheny National Forest for use in ecosystem management studies and planning.