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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.

PREPARATION OF FOREST INVENTORY AND ANALYSIS (FIA) AND STATE SOIL GEOGRAPHIC DATA BASE (STATSGO) DATA FOR GLOBAL CHANGE RESEARCH IN THE EASTERN UNITED STATES

Louis R. Iverson, Anantha M.G. Prasad, and Charles T. Scott[1]

Abstract: The USDA Forest Service's Forest Inventory and Analysis (FIA) and the Natural Resource Conservation Service's State Soil Geographic (STATSGO) data bases provide valuable natural resource data that can be analyzed at the national scale. When coupled with other data (e.g., climate), these data bases can provide insights into factors associated with current and future ranges of tree species. However, a significant amount of data distillation is needed prior to such analyses. This paper describes the data base and geographic information system (GIS) processing involved with preparing the data for global change research in the eastern United States.

INTRODUCTION

To better understand the potential impacts of climate change on tree-species distributions (i.e., migration potentials), one must first understand the factors associated with current tree ranges. Then, projections of future ranges can be made assuming there are no barriers to migration. Finally, more realistic projections of migration can be modeled with proper attention to habitat and biological restrictions to migration. This paper reports on initial efforts in this overall project.

For purposes of coarse resolution analysis at the national scale, especially in the eastern United States, a county level of resolution seems appropriate. There are 3,048 counties across 37 states east of the 100th meridian. This level of detail allows several advantages over finer (e.g., individual plots or soil series) or coarser (e.g., ecoregions) levels of detail: (1) the data set is manageable in size and computing power, yet of sufficient detail for adequate sample sizes, (2) data are more readily available, as many agencies report data at the county level, and (3) precise spatial co-location of forest inventory plots and ancillary information is not necessary with a county level of resolution. However, any averaging of forest or soil information to the county will lose information, especially in counties with highly heterogeneous habitats. Nonetheless, given the advantages of such a level of analysis, a procedure to recalculate data to the county reporting unit was needed. This paper describes the procedures we used for two national-level data bases: the USDA Forest Service's Forest Inventory and Analysis (FIA) and the Natural Resources Conservation Service's State Soil Geographic data bases.

For both data sets, we used Arc/InfoAML and UNIX shell programming (especially 'awk' and 'sed') running on a workstation. We developed a series of macro programs that did the desired operations on one state's data at a time. Nearly two gigabytes of data storage were needed to store and process the information for U.S. land east of the 100th meridian.

FOREST INVENTORY AND ANALYSIS DATA BASE

The USDA Forest Service has a mandate to periodically determine the extent, condition, and volume of timber, growth, and removals of the nation's forest land. The six Forest Service FIA units conduct periodic regional surveys. Four FIA units produced a data base of standard format called the Eastwide Data Base (EWDB) for the 37 states from North Dakota to Texas and east. These data are stored in three record types as described in their user's guide (Hansen et al. 1992): county data, plot data, and tree data. These 500 megabytes of 'raw' data were summarized into the desired county-level information needed for our global change research.

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Extraction of individual tree-species information

The first step summarized the information for individual forested plots. Tree records represented observations of seedlings, saplings, and overstory trees. Tree species, tree status, and diameter at breast height were combined with information on plot size to compute a single summary record for each plot. The record contained the following information for each species that occurred in the state: number of understory trees/acre, understory basal area/acre, number of overstory trees/acre, and overstory basal area/acre. This information provided the next step in the FIA data summary.

Importance value calculation by species

Once the number of stems and basal area were available for each species (overstory vs. understory) for each plot, the relative importance of each species could be evaluated. Several importance values were calculated depending on the choice of variables considered (i.e., overstory vs. understory, basal area vs. number of stems). The overall importance value (IV) can be described as

$$IV(x) = \frac{100\,BA(x)}{BA(all species)} + \frac{100\,NS(x)}{NS(all species)}$$

where x is a particular species on a plot, BA is basal area, and NS is number of stems for both overstory and understory trees. On monotypic stands, the IV would reach the maximum of 200.

Mapping by plot

Importance values for any species could then be mapped by plot assuming that specific locations of the plots were available. Plot locations are truncated to 100 seconds (roughly 1000 m at this latitude) in the EWDB to protect the precise location of the long-term remeasurement plots. Under special arrangement with the FIA units, we obtained plot locations for Ohio, Kentucky, Illinois, and Indiana, our region of special interest for more detailed analysis. A method was devised by which importance values were divided into cartelist, with different symbols used for each cartel. Therefore, a quick visual inspection of the maps could determine where the species was found and how extensive it was relative to the other trees in the plots

Aggregation and mapping at county level

To aggregate plot-level information to the county level, no GIS processing was necessary until final mapping since each plot has a county code associated with it. Average importance values were calculated for all forested plots, by species and by county. These values were associated with a county coverage of the United States (SRI 1992) for mapping into density slices of IV (Fig. 1 a). With these maps, biogeographical characteristics (such as absolute and optimum range) of the species can be visualized. Current research involves statistical analysis of the range relative to other variables and a better characterization of eastern forest tree species

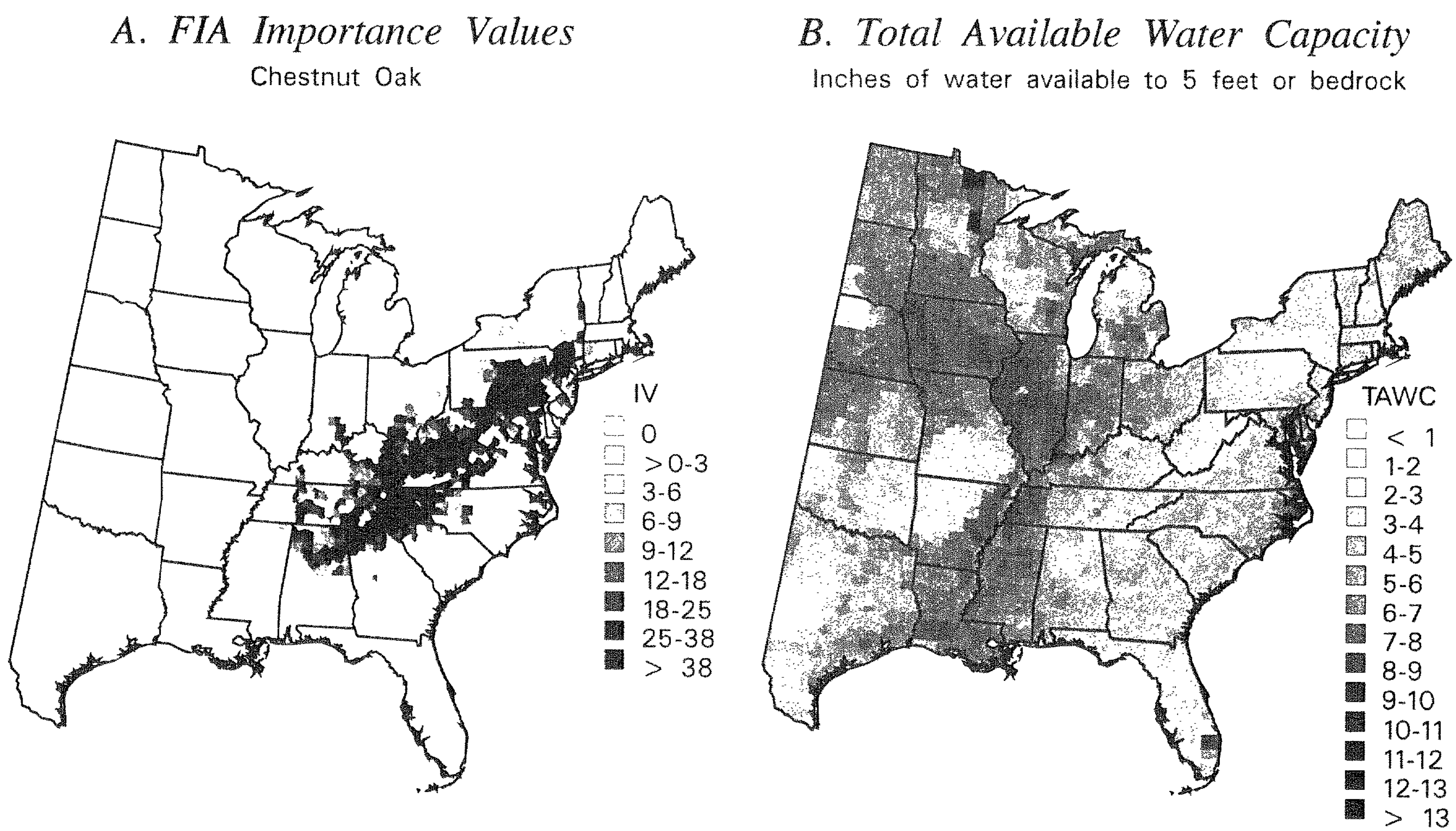

Figure 1. A. Importance values for chestnut oak, and B. Total water capacity for the eastern United States.

STATE SOIL GEOGRAPHIC DATA BASE

The State Soil Geographic Data Base (STATSGO) was developed by the USDA Soil Conservation Service (now Natural Resource Conservation Service) to help achieve their mandate to collect, store, maintain, and distribute soil-survey information for U.S. lands. STATSGO data recently became available for the entire nation on CD; it contains physical and chemical soil properties for about 18,000 soil series recognized in the nation (Soil Conservation Service 1991). STATSGO maps were compiled by generalizing more detailed soil-survey maps into soil associations in a scale (1: C) more appropriate for regional analysis. Detailed, digital soil-survey maps are available only for scattered portions of the country and requirements for data storage would be enormous. Therefore, STATSGO data currently are one of the best sources of information on the edifice landscape pattern and structure for the nation. However, the nature of the data dictates a sizable amount of preprocessing is necessary before maps of particular attributes can be produced on a national scale.

Attribute selection

STATSGO's user's guide (Soil Conservation Service, 1991) details the data structure and the myriad of files and variables contained within. For purposes of global change research, we selected 14 variables related to tree species habitat: pH, available water capacity, organic matter, permeability, bulk density, salinity, cation exchange capacity, depth to bedrock, T factor, K factor, slope, and several variables related to texture (e.g., percent clay, percent fragments > 3 inches, percent volume of soil flowing through screens with meshes of various sizes).

Weighted averaging by depth, soil-series composition, and county

Except for depth to bedrock, T factor, K factor, slope, and organic matter, each variable had estimates in STATSGO by individual layer in the horizon. A weighted average, based on the thickness of each layer to a depth of 60 inches (152 cm) or the depth to bedrock, was calculated for each soil series. A second weighted average was calculated for the horizontal dimension based on the percent composition of each soil series within each soil association. Since mapping units were associations, maps of any of the extracted variables could then be made at the association level. Finally, a third weighted average was calculated to estimate attributes by county. The proportion of each soil association within each county (an intersection of county coverage with STATSGO associations) was multiplied by the attribute weighted average for each association and summed for the county. Again, the county weighted averages can be mapped for any variable, as exemplified by available water capacity for the eastern United States (Fig. 1b).

SUMMARY

The two data bases described here provide valuable resources for natural resource evaluation and environmental assessment, including modeling impacts of potential climate change, at a regional level. Both data sets are only recently available in standard format for such a large portion of the country. Because of limitations in spatial accuracy, computer power, and data storage, a county-level analysis seems appropriate for revealing relationships between these data sets and others such as climate, elevation, or land use. At this scale, one can look a level up to understand context and a level down to understand process. Thus, the effort described here was necessary to get the data in a form useful for such analyses. Table 1 summarizes some information contained within the data bases, by state.

Table 1. Summary of selected FIA and STATSGO data by state. Column abbreviations include number of forested and total plots in the FIA data base, percent forest (from Powell et al. 1993), number of tree species recorded in FIA data, number of soil associations in STATSGO data, number of counties, and the date of the forest inventory in the FIA data base.

State	No. forest plts	No. plts	Forest, %	No. spp	No. soils	No. cnty	Date, fia
Alabama	4013	4515	67.7	117	251	67	1990
Arkansas	3158	3786	53.6	105	68	75	1988
Connecticut	286	463	58.7	61	31	8	1985
Delaware	149	250	31.1	59	19	3	1986
Florida	5377	12441	47.9	68	159	67	1987
Georgia	7152	12015	65.1	84	112	160	1988
Illinois	1132	10957	12.0	86	83	102	1985
Indiana	2146	11440	19.3	94	93	92	1986
Iowa	699	12767	5.7	63	83	99	1990
Kentucky	1995	3049	50.0	107	195	120	1988
Louisiana	2473	2893	49.7	99	336	64	1991
Maine	2161	2483	88.8	62	69	16	1982
Maryland	691	1199	42.9	98	63	23	1986
Massachusetts	379	555	63.9	71	61	14	1985
Michigan	7931	14958	50.2	81	190	83	1980
Minnesota	12260	43955	32.8	60	321	87	1990
Mississippi	3003	3618	56.6	104	215	82	1987
Missouri	3861	17270	31.8	90	106	115	1989
New Hampshire	590	697	86.8	58	45	10	1983
New Jersey	259	644	42.3	77	39	21	1987
New York	2501	4313	61.9	86	168	62	1980
North Carolina	5696	9993	61.8	90	75	100	1990
Ohio	1762	4845	30.0	104	166	88	1991
Pennsylvania	3128	5298	59.2	103	103	67	1989
Rhode Island	116	179	59.9	46	18	5	1985
South Carolina	4383	7031	63.6	85	158	46	1993
Tennessee	2350	2951	51.6	113	214	95	1989
Vermont	625	823	76.7	61	76	14	1983
Virginia	4285	7312	62.6	87	76	95	1991
West Virginia	2592	3209	78.7	109	122	55	1989
Wisconsin	6939	15908	44.6	67	128	72	1983

Future efforts entail building and enhancing data bases on elevation, climate and land use for the eastern United States, and conducting statistical analysis (e.g., regression, decision-tree, and correspondence analysis) designed to better understand the current distribution of eastern trees. Then, predictions of range changes can be made (under ideal conditions of seed source availability and habitat availability) following a climate change. Finally, models under development will help determine how well species can migrate under the real situation of fragmented habitats.

ACKNOWLEDGMENTS

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REGENERATION ATTRIBUTES OF TREE SPECIES IN THE CENTRAL HARDWOODS TYPE

Elaine Kennedy Sutherland[1], Betsy J. Hale[2], and David M. Hix[2]

Processes relating to tree regeneration are many and complex. To develop generalized conceptual models of tree regeneration, we synthesized information from the forest ecology literature. We produced a list of 21 regeneration attributes that describe flowering, seed production, seed dispersal, dormancy, germination environment, seedling characteristics, and vegetative reproduction. Attributes were classified for each of 62 tree species in the central portion of the eastern hardwoods region. The resulting data are categorical, both nominal and ordinal. We applied multivariate techniques to determine which species were similar and which attributes contributed most to species groupings, with special attention to constraints of categorical data. Based on Jaccard's similarity coefficient and Ward's clustering method, seven species clusters were evident. Given the correlations from Bray-Curtis ordination, thirteen attributes that contributed strongly to the groupings (univariate F-tests, $p < .05$) are being used to develop conceptual models of the regeneration pathways for each group. The pathways will be parameterized for each species, and then used to develop a rule-based mechanistic model of tree regeneration (Mechanistic Origination Model: MOM). We will continue to apply the same techniques to other regions (eg., northern hardwoods).

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HERBIVOROUS INSECTS AND CLIMATE CHANGE: POTENTIAL CHANGES IN THE SPATIAL DISTRIBUTION OF FOREST DEFOLIATOR OUTBREAKS

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The geographical ranges and spatial extent of outbreaks of herbivorous insect species are likely to shift with climatic change. We investigate potential changes in spatial distribution of outbreaks of the western spruce budworm, *Choristoneura occidentalis* Freeman, in Oregon and the gypsy moth, *Lymantria dispar* (L.), in Pennsylvania using maps of historical defoliation, climate, and forest composition in a geographic information system. Maps of defoliation frequency were assembled using historical aerial reconnaissance data. Maps of monthly means of daily temperature maxima and minima and of monthly precipitation averaged over 30 years were developed using an interpolation technique. All maps were at a spatial resolution of 2 × 2 km. Relationships between defoliation status and the environmental variables were modeled using a linear discriminant function. Five climatic change scenarios were investigated: an increase of 2 °C, a 2 °C increase with an increase of 0.5 mm per day in precipitation, a 2 °C increase with an equivalent decrease in precipitation, and equilibrium projections of temperature and precipitation by two general circulation models (GCMs) at doubled CO_2 levels.

With an increase in temperature alone, the projected defoliated area decreased relative to ambient conditions for the budworm and increased slightly for the gypsy moth. With an increase in temperature and precipitation, the defoliated area increased for both species. Conversely, the defoliated area decreased for both when temperature increased and precipitation decreased. Results for the GCM scenarios contrasted sharply. Using the scenario projected by the Geophysical Fluids Dynamics Laboratory (GFDL) GCM, defoliation by budworm was projected to cover Oregon completely, whereas no defoliation was projected by gypsy moth in Pennsylvania. Under the scenario projected by the Goddard Institute for Space Studies (GISS) GCM, defoliation disappeared completely for the budworm and slightly exceeded that under ambient conditions for the gypsy moth. The results are discussed in terms of potential changes in forest species composition.

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PREDICTING THE EFFECTS OF TROPOSPHERIC OZONE ON FOREST PRODUCTIVITY IN THE NORTHEASTERN U.S.

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Abstract: It is widely believed that tropospheric ozone presents a significant anthropogenic stress on forest ecosystems. Although much information has been collected regarding ozone effects at the seedling and leaf level, we do not have a reliable means of estimating the effect on mature, native forests. For the present study, we incorporated leaf-level ozone response information into an ecosystem model of forest production known as PnET-II in order to make whole-forest predictions that account for factors such as light attenuation, canopy ozone gradients and water stress. We ran the model using ambient ozone data from 64 locations across New York and New England. Predictions indicate reductions in annual NPP of from 2 to 17 percent under mean ozone from 1987-1992. Reductions were greatest in southern portions of the region on soils where drought stress was absent.

INTRODUCTION

The formation of ozone in the lower atmosphere poses a serious threat to forest growth in industrialized regions. Controlled exposure studies have shown that concentrations observed in ambient air cause substantial reductions in plant productivity. Observed effects include decreased photosynthetic rates (Reich and Amundson 1985, Pell *et al.* 1992), impaired stomatal function (Reich and Lassoie 1984), decreased biomass production (Shafer 1987, Wang *et al.* 1985), visible foliar injury (Hill *et al.* 1970), and accelerated foliar senescence (Swank and Vose 1991).

Data from these studies have been used to establish response relationships whereby reductions in photosynthesis are related to ozone exposure levels (Reich 1987). However, these relationships by themselves are insufficient for predicting whole-forest growth effects. Factors such as light availability, photosynthetic capacity and ozone concentrations vary within a forest canopy, but the outcome of these interactions cannot be estimated from studies conducted on seedlings or individual branches alone (Pye 1988).

The purpose of this study was to combine leaf-level ozone response data with a physiologically-based forest ecosystem model known as PnET-II in order to allow ozone response relationships to interact with important canopy-level factors. Our approach was to summarize the effects of ozone on net photosynthesis at the leaf interior by relating reductions in net photosynthesis to ozone uptake, as opposed to external dose or concentration. This is important since factors affecting leaf conductance can greatly alter plant response to a given external dose. The resulting equations were built into the PnET-II model and applied to individual canopy layers in order to calculate integrated, whole-canopy responses.

MODEL DEVELOPMENT

PnET-II

PnET-II is a monthly time step canopy- to stand-level model that is built on the following relationships: 1) maximum leaf photosynthetic rate is a linear function of foliar nitrogen content, each expressed on a mass basis

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(Aber and Federer 1992, Reich *et al.* 1995), and 2) water use efficiency is inversely proportional to vapor pressure deficit (Aber and Federer 1992). The simulated forest canopy is divided into multiple, even-mass layers to account for vertical variation in available light and specific leaf weight (Ellsworth and Reich 1993). The model has been successfully validated for forest production and CO_2 exchange at diverse locations across North America (Aber and Federer 1992, Aber *et al.* 1995a, 1995b).

Ozone response relationships

Data from ozone fumigation experiments indicate a strong relationship between cumulative ozone dose and reductions in net photosynthesis (Reich 1987). This impact varies greatly between species, although much of the variation can be explained by differences in stomatal conductance (Guderian et al. 1985, Reich 1987). Because conductance is the most important regulator of ozone uptake under a given external concentration (Taylor *et al.* 1994, Munger *et al.* 1994), this suggests that ozone effects on net photosynthesis can be expressed largely as a function of how much ozone reaches the leaf interior.

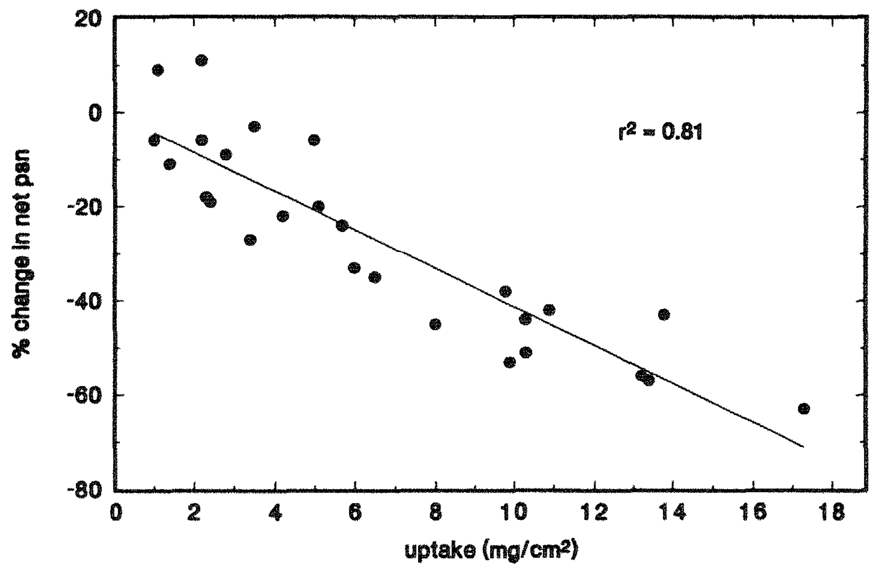

Figure 1. Percent reduction in net photosynthesis in relation to ozone uptake for hardwoods. From Reich 1987.

It follows that across species, declines in net photosynthesis should be better correlated with ozone uptake than with external concentration or dose. Figure 1 shows this relationship using data from independent studies conducted over periods of several days to several months on a wide variety of hardwood seedlings (from Reich 1987). Tjoelker *et al.* (1995) obtained similar results from mature sugar maple leaves in a partial-canopy, open-air fumigation study conducted over a period of three months. Using pooled data from figure 1 and Tjoelker *et al.* (1995), we have derived the following response equation.

1) $dO_3 = 1 - (.0026 * g * D40)$

where dO_3 is the ratio of ozone-exposed to control photosynthesis, g is mean stomatal conductance (in mm/sec) and D40 is the cumulative ozone dose (in ppm-h) above a threshold concentration of 40 ppb, calculated as the sum of all hourly values > 40 ppb after subtracting 40 from each. We use this threshold because 40 ppb is approximately the level at which negative impacts begin to appear in the pooled data set. Several other studies have also found 40 ppb to be the threshold beyond which negative growth effects begin to occur (Fuhrer 1994, McLaughlin and Downing 1995).

Canopy ozone gradients

We evaluated ozone gradients within a forest canopy using data from Munger *et al.* (1994), which includes three years of measurements along a vertical profile through a mixed hardwood forest at the Harvard Forest in central Massachusetts. For all months of the growing season we calculated the D40 value at each canopy level and plotted the resulting gradients. Figure 2 shows these gradients for May and July of 1992, during which times, ozone below the canopy decreased to 72 and 18 percent of the above-canopy D40, respectively. The shape of these patterns is such that, even during months of substantial canopy depletion, ozone levels remain high in the upper canopy layers where light levels and photosynthetic rates are greatest. For all three years, canopy ozone depletion increased from spring through midsummer and declined at the end of the growing season. These trends can be described by the equation:

2) $dD40_{level} = 1 - (level * a)^3$

where $dD40_{level}$ is the proportion of the above-canopy D40 at a given canopy level, *level* is the normalized canopy level from 0 at the ground to 1 at the top of the canopy, and *a* is the ozone extinction coefficient that is determined for each month from mean monthly D40 values. Table 1 shows mean values of *a* along with the corresponding absolute canopy gradient in D40 for each month of the growing season from 1991 to 1993.

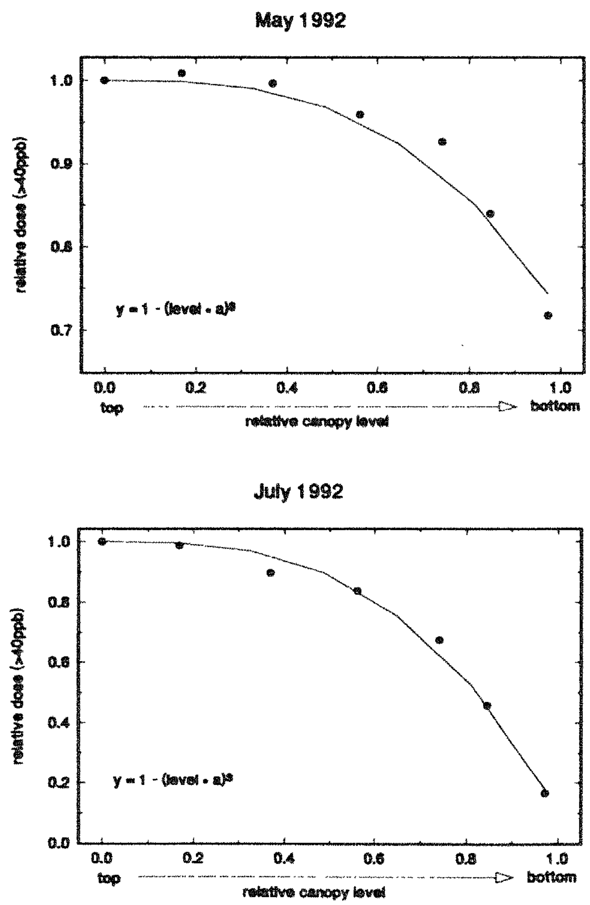

Figure 2. Ozone dose > 40ppb in relation to canopy position at the Harvard Forest in Central Massachusetts. Both axes have been normalized to a scale of 0 to 1. Data are from Munger *et al.* 1994.

Table 1. Solutions to equation 2, showing mean canopy depletion of ozone D40 between 1991 and 1993.

Month	*a* (from eq. 2)	R^2	% decrease from above to below canopy
May	.6776	.96	31
June	.8388	.94	61
July	.9310	.98	75
August	.9243	.96	75
September	.9449	.98	77
October	.8333	.94	61

Incorporation of ozone effects into PnET-II

For the prediction of ozone effects on whole-forest growth, equation 1 has been built into the PnET-II model's photosynthesis routine at the level of individual canopy layers. For each layer, leaf conductance is calculated as a function of potential net photosynthesis, and is thus affected by available light at that layer, foliar nitrogen content, and temperature. Monthly D40 values are estimated for each canopy layer by combining ambient concentrations with the mean 1991-93 ozone depletion profiles (from equation 2 and table 1). Ozone effects are determined from May through October and are calculated cumulatively for each layer.

Conductance (*g*) is calculated as a linear function of net photosynthesis, based on a strong relationship ($r^2 = 0.93$) between the two among data in the literature (Abrams *et al.* 1990, Amthor *et al.* 1990, Aubuchon *et al.* 1978, and Hinckley *et al.* 1978). In equation 1, ozone uptake is approximated by the product of *g* and D40. Because *g* represents conductance to water vapor, calculating actual uptake rates would require inclusion of the diffusivity ratio of water vapor to ozone. However, because this ratio is a constant, it's inclusion in the derivation and application of equation 1 would have no effect on the resulting predictions. For simplicity we have left it out of the equation.

Given the relationship between conductance and net photosynthesis, ozone exposure might be expected to cause conductance to decline along with photosynthesis, resulting in a reduction of subsequent ozone uptake. Reduced leaf conductance has been observed in many studies, although the effect is often minimal with respect to the photosynthetic response (e.g. Pell *et al.* 1992), or reversed under certain light regimes (*e.g.* Reich and Lassoie 1984, Volin *et al.* 1993). In one of the only open-air exposure studies performed on a mature tree canopy under field conditions, there was virtually no change in conductance (and hence ozone uptake) despite large reductions in photosynthesis (Tjoelker *et al.* 1995). This lack of a response suggests impairment of stomatal function, as the net effect is an uncoupling of the normal relationship between photosynthesis and conductance (Volin *et al.* 1993, Tjolker *et al.* 1995).

In the absence of consistent and predictable changes in conductance, we have not included any such feedback in the present modeling exercise. Inconsistencies in observed stomatal response indicate a lack of understanding of how ozone affects leaf conductance, but because photosynthetic responses are generally much greater than, and typically precede changes in conductance (when such changes have been observed), this should not be a crucial issue in predicting ozone effects on whole-forest productivity.

Interactions between ozone and drought

For each canopy layer, the model tracks photosynthesis with and without ozone in order to determine the potential, whole-canopy ozone effect and to allow interaction with drought stress, which is calculated for the entire canopy as opposed to individual leaf layers. After the calculation of potential canopy photosynthesis (without ozone or water limitations), the PnET-II model's water balance routine determines potential transpiration and performs a comparison with the amount of available soil moisture. If soil moisture is not adequate to meet the transpirational demand, water stress ensues and canopy photosynthesis is reduced.

Because the primary physiological response to water limitation is stomatal closure and ozone effects are linearly related to stomatal conductance, the potential (no water limitation) whole-canopy ozone effect is reduced proportionally to the degree of water stress. For example, if water stress causes a 20 percent reduction in potential photosynthesis (*d*Water = 0.8), and the potential whole-canopy ozone effect is also a 20 percent reduction, the final ozone effect is reduced by a factor of 0.8 to 16 percent ($dO_3 = 0.84$).

MODEL APPLICATION

We have run the model for hardwood forests across the northeastern U.S. using ozone data obtained from the U.S. Environmental Protection Agency's Aerometric Information Retrieval System (AIRS) between 1987 and 1992. For each collection station, we used raw, hourly data to determine the monthly dose above 40 ppb. We only considered measurements from between 7AM and 7PM to exclude unusually high nighttime concentrations. To minimize error caused by missing data, a 90 percent completeness criterion was imposed whereby any month containing less than 90 percent of the expected number of observations was not used in calculating long-term monthly means. The resulting data set included 64 sites with average monthly values determined from 3 to 7 years of data (figure 3). In computing long-term mean values, some bias between sites may result from differences in the years for which data were available.

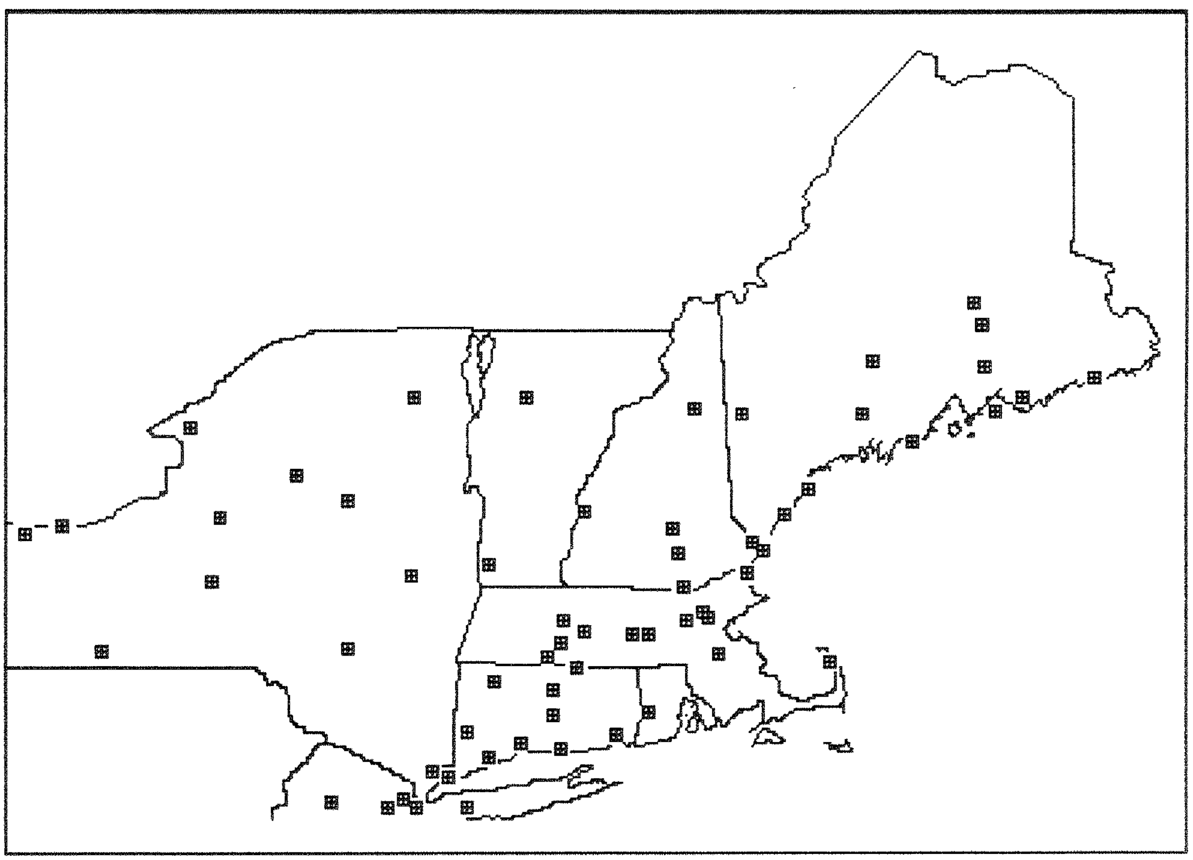

Figure 3. Locations of EPA ozone monitoring stations.

Climate data required by the PnET-II model were calculated for each of the 64 ozone data sites using a statistical climate model derived for the region from 30 year mean weather station data (Ollinger *et al.* 1995). We used a foliar nitrogen value of 2.2 percent, based on values measured at the Harvard Forest (Martin and Aber 1995). In the absence of soil water holding capacity (WHC) data from each site, we have run the model under several conditions ranging from high to low WHC.

RESULTS AND DISCUSSION

Results of initial model runs indicate decreases in annual net primary production (NPP) of from 2 to 17 percent as a result of mean ozone levels from 1987-1992 (figure 4) with greatest reductions in southern New York and New England where ozone levels and potential photosynthesis were greatest. The predicted decrease was negatively correlated with latitude, following a trend of decreasing ozone from south to north across the region. Predictions varied significantly across the range of soil WHC values used (2-36 cm.), although ozone-induced growth reductions were substantial even on soils with low WHC (figure 4).

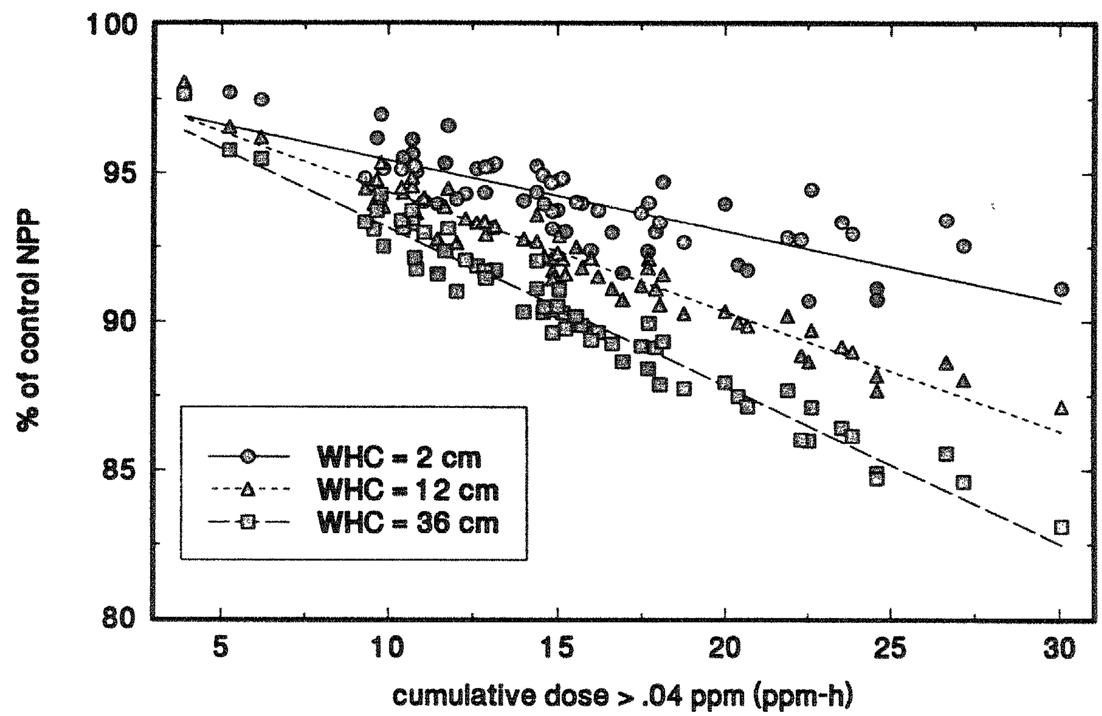

Figure 4. Predicted change in annual NPP at 64 sites across the study region in response to mean ozone levels from 1987-1992. Predictions are shown for three levels of soil water holding capacity to show how the response changes from well-watered (WHC = 36) to drought-stressed (WHC = 2) conditions.

Table 2 shows means and ranges of predicted NPP for the 64 sites under all soil WHC values used. At WHC = 36 cm, all predicted drought stress was eliminated, so these values can be used as a reference in estimating drought effects resulting from other moisture conditions. Under all but the two wettest conditions, drought stress caused greater growth reductions than ozone. At WHC = 12 cm, which represents a typical well-drained till soil, ozone effects on NPP were roughly 25 percent less than what was predicted in the absence of drought stress.

Table 2. Mean predicted NPP (g/m^2yr) across the 64 study sites with and without ozone effects at 5 levels of soil water holding capacity (cm).

Soil WHC	NPP without ozone mean	NPP without ozone range	NPP with ozone mean	NPP with ozone range	mean % reduction
2	723	640-776	680	591-734	5.9
6	1136	991-1230	1048	915-1151	7.7
12	1354	1187-1475	1247	1190-1372	7.9
24	1732	1574-1846	1573	1411-1699	9.2
36	1840	1645-1993	1659	1527-1807	9.8

We consider these predictions to be conservative in that ozone effects are based solely on reductions in photosynthesis. Although this is generally accepted as the major physiological effect of ozone, other responses may also be important, particularly under circumstances such as unusually high concentration events. Nevertheless, current predictions do suggest substantial declines in NPP among forests across the northeast region. Although we have not addressed ozone effects on wood production, we expect wood to be affected to a greater extent than NPP because wood is a relatively low priority in tree carbon allocation.

In addition to ozone, other factors such as land use and atmospheric nitrogen deposition can have substantial impacts on ecosystems. Determining the net effect of human activities on forest growth thus requires consideration of all these factors taken together, rather than any one on its own. Although the outcome of these interactions remains largely unknown, this study suggests that concern over ozone as a cause of ecological and economic degradation is warranted.

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CATALOG OF LONG-TERM RESEARCH CONDUCTED WITHIN THE USDA FOREST SERVICE, NORTHEASTERN FOREST EXPERIMENT STATION

Hope R. Barrett[1]

Long-term data sets are described in a catalog to reduce duplication of scientific efforts and to facilitate interaction among researchers. Individual entries for each of 90 long-term data sets include details such as site characteristics, variable names, year collected, sampling design, data storage method, intended purpose of the data set and potential application to global change research. Catalog entries are organized according to common study topics into 29 themes such as forest monitoring: vegetation in unmanaged forests, fertilization: effects on stream water, birds: habitat relationships, insects: population dynamics and soils: characteristics associated with plants. Themes contain as few as one and as many as 25 entries. Some multipurpose entries are categorized under more than one theme.

Reviews affirm the catalog is easy to use, informative and will cultivate productive communication among researchers. A secondary result is that scientists are expressing a renewed and attentive awareness toward the management of long-term data. The resources employed to develop a database of metadata are substantiated as long as higher quality research is a result of better awareness. The catalog, forthcoming as a Forest Service publication with dBASE format, is already in high demand. Several options have been encouraged as ways to make the catalog accessible through the Internet. The Station and the Northern Global Change Research Program share a commitment to maintain and update their investment in high quality research data.

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