United States
Department of
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**Northeastern
Research Station**

General Technical
Report NE-265

Atlas of Current and Potential Future Distributions of Common Trees of the Eastern United States

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Anantha M. Prasad
Betsy J. Hale
Elaine Kennedy Sutherland

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Abstract

This atlas documents the current and possible future distribution of 80 common tree species in the Eastern United States and gives detailed information on environmental characteristics defining these distributions. Also included are outlines of life history characteristics and summary statistics for these species. Much of the data are derived from Forest Inventory and Analysis (FIA) data, analyzed in concert with 33 environmental variables within a geographic information system. Life history information, including regeneration and disturbance characteristics, were generated via the literature and are provided in data base format. Summary statistics offer an overall perspective on the tree species of the eastern United States. Regression tree analysis models were constructed to determine possible future habitat for each species under two scenarios of global climate change. Results show that, depending on the scenario, 4-8 of the 80 species could be extirpated from the Eastern United States after climate change. Appendices provide information on the data and methods used, including demonstration of a migration model.

Keywords: *Eastern United States, global change, geographic information systems, forest inventory and analysis, trees, landscape ecology, species distribution*

The Authors

LOUIS R. IVERSON is a research landscape ecologist, Northeastern Research Station of the U.S. Department of Agriculture, Forest Service, stationed at 359 Main Road, Delaware, OH 43015. email: *liverson@fs.fed.us*

ANANTHA M. PRASAD is an ecologist, Northeastern Research Station of the U.S. Department of Agriculture, Forest Service, stationed at 359 Main Road, Delaware, OH 43015. email: *aprasad/@fs.fed.us*

BETSY J. HALE is a research forester, Northeastern Research Station of the U.S. Department of Agriculture, Forest Service, stationed at 359 Main Road, Delaware, OH 43015.

ELAINE KENNEDY SUTHERLAND is a research biological scientist, Rocky Mountain Research Station of the U.S. Department of Agriculture, Forest Service, stationed at 800 Block East Beckwith, P.O. Box 8089, Missoula, MT 59807. email: *esutherland@fs.fed.us*

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Contents

Acknowledgments

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Introduction

Forests of the Eastern United States are diverse and productive; however, their character is changing. Fire suppression and deer overabundance are reducing the regeneration of oak species and eastern hemlocks, and other species such as red maple are becoming dominant over much of the region. In the northeastern United States, sugar maples are in decline. The gypsy moth continues to spread westward, and the Asian long-horned beetle has just begun its attack on eastern forests. Diseases, such as the dogwood anthracnose on dogwoods, continue to plague many species. And the continued warming trend that we have seen for several decades will impact the distribution of forests, especially if the warming trend continues into the next century (Neilson and Chaney 1997; Shriner and Street 1998).

The purpose of this atlas is to highlight the status of the current forests of the United States, east of the 100th meridian. We present 80 common tree species, describe their current importance geographically, and determine the relationship of many environmental variables to the importance of each species through geographic information system (GIS) and statistical analysis. We also have compiled life history information on each species. This information supplements the *Silvics of North America* handbooks (Burns and Honkala 1990a,b) that are excellent compilations of the silvical characteristics of trees of the United States. The atlas complements several other excellent books covering the forest resources of North America (for example, Barbour and Billings 1998; Elias 1980; Farrar 1995; Leopold et al. 1998; Walker 1999). In the atlas, we map, summarize, categorize, and compare species in a concise format, based on real data from field plots as well as the literature. We also use a statistical modeling approach to estimate distributional changes that could occur under a globally changed climate, according to two global circulation model (GCM) scenarios. The predicted changes in distribution as a result of climate change presented here are not highly reliable due to uncertainties and underlying assumptions. They do, however, provide a picture of the sensitivity of species to climate change, the environmental variables that drive the current distribution, and the kind of distributional changes that could occur under a warmed climate. Some of the changes could be truly dramatic.

The atlas is organized into four parts. Part 1 summarizes attributes of the current and predicted future distributions of species, along with a model of critical environmental variables that describe the current distribution of abundance. We present these analyses for each species through tables, graphs, and maps. Part 2 summarizes life history information, especially as it pertains to regeneration, in a data-base format. Extra emphasis in this section is given to responses from disturbances, especially fire (because this topic is not reported well elsewhere). Part 3 summarizes many ecological and biogeographical characteristics among the 80 species through a series of charts. It provides a basis for comparison among species, as well as an overall assessment of species characteristics. Finally, in Part 4, the appendices provide data sources and methodologies used in this work, and a 'preview' of ongoing research that models migration across fragmented landscapes over the next 100 years. We hope that this publication can provide researchers, educators and students, land managers, naturalists, politicians, and the interested public with the tools to learn more about our rich forests, the trees that occupy them, and the potential changes that could occur due to global change.

Data Sources and Analyses

Several sources of data were used for this atlas. The primary data source for tree abundance and distribution was the USDA Forest Service's Forest Inventory and Analysis (FIA) data. Data from more than 100,000 forested field plots were used to prepare the maps shown in this atlas. Details on the data and how importance values (IV) were calculated are given in Appendix A. The range boundaries prepared by Little (1971, 1977) were used to supplement the FIA data.

We also acquired and analyzed environmental data from numerous sources to assess relationships between tree species importance values and the environment in which they grow. A total of 33 variables were analyzed, including variables on climate, potential future climate, soils, land use/cover, elevation, and landscape pattern (Table 1). Representative data from each of these categories are mapped in Figure 1. A description of the environmental variables is given in Appendix B.

We used a process called regression tree analysis (RTA) to relate FIA species abundance data to environmental data to build statistical models describing the species distributions. These statistical models were then used, along with models of future climate, to project potential future distributions under a globally changed climate. Details of this process, and the assumptions associated with the modeling, are given in Appendix C.

Finally, we extend the process in an example for one species (*Pinus virginiana*) and model the potential migration of the species across the fragmented landscape of today (Appendix D). In this example, we use the outputs of the atlas maps as the potential (=suitable) habitat into which a species may migrate, and use simulation modeling to project the possible migration after 100 years, assuming migration rates similar to that which occurred after the last glaciation.

Table 1. County environmental and land-use variables used for this atlas.

Abbreviation	Variable	Frequency[a]	Cumulative score[b]
	Climatic Factors		
AVGT	Mean annual temperature (°C)	47	12.0
JANT	Mean January temperature (°C)	115	34.8
JULT	Mean July temperature (°C)	44	9.6
PPT	Annual precipitation (mm)	79	12.9
PET	Potential evapotranspiration (mm/month)	70	17.6
MAYSEPT	Mean May-September temperature (°C)	30	9.1
JARPPET	July-August ratio of precipitation to PET	27	6.1
	Soil Factors		
TAWC	Total available water-holding capacity (cm, to 152 cm)	47	6.9
CEC	Cation exchange capacity	58	8.5
PH	Soil pH	45	8.9
PERM	Soil permeability rate (cm/hour)	75	15.4
CLAY	Percent clay (< 0.002 mm size)	66	12.4
BD	Soil bulk density (g/m^2)	50	5.7
KFFACT	Soil erodibility factor, rock fragments free	92	23.2
OM	Organic matter content (% by weight)	60	13.0
ROCKFRAG	Percent weight of rock fragments 8-25 cm	54	9.7
NO10	Percent passing sieve No. 10 (coarse)	43	6.5
NO200	Percent passing sieve No. 200 (fine)	46	10.5
ROCKDEP	Depth to bedrock (cm)	29	2.8
SLOPE	Soil slope (percent)	57	15.7
PROD	Potential soil productivity (m^3 of timber/ha)	61	12.2
ALFISOL	Alfisol (%)	34	9.3
INCEPTSL	Inceptisol (%)	14	1.9
MOLLISOL	Mollisol (%)	30	7.9
SPODOSOL	Spodosol (%)	13	2.6
	Land use/cover factors		
FORST.LND	Forest land (%)	54	6.7
CROPS	Cropland (%)	46	13.9
GRAZE.PST	Grazing pasture land (%)	54	8.6
DIST.LND	Disturbed land (%)	35	4.0
	Elevation		
MAX.ELV	Maximum elevation (m)	67	18.3
MIN.ELV	Minimum elevation (m)	46	6.6
ELV.CV	Elevation coefficient of variation	46	8.0
	Landscape Pattern		
ED	Edge density (m/ha)	50	6.4

[a]Frequency indicates the cumulative number of times the variable appeared in the models and is therefore a measure of variable importance (a variable can appear in a model more than once so that frequency can exceed 80, the total of all species).

[b]Cumulative score is an overall index of variable importance across all species, calculated by taking the sum of 1/rank for all 80 species.

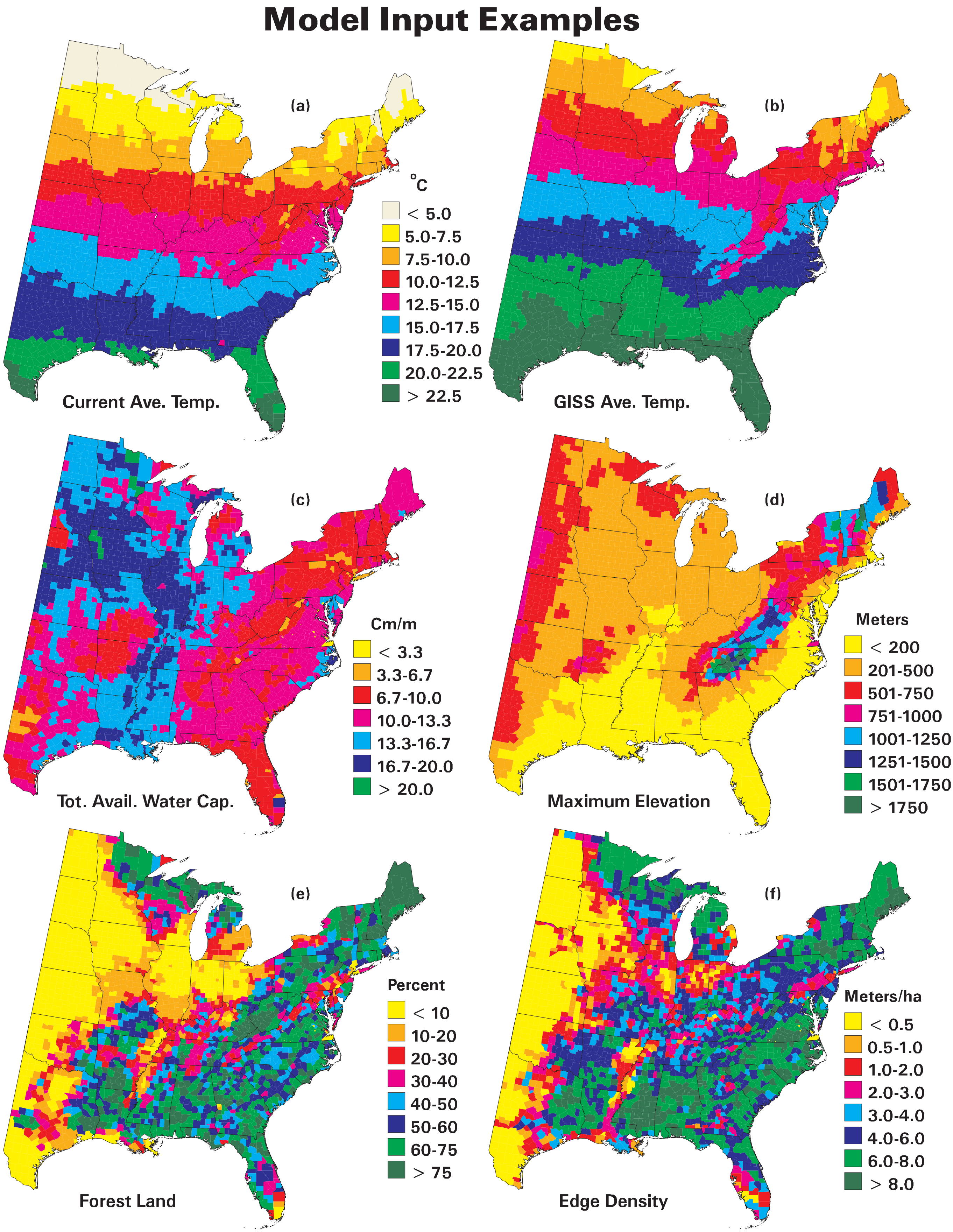

Figure 1.–Examples of six environmental variables used in this study: (a) current average temperature, (b) GISS average temperature, (c) total available water capacity, (d) maximum elevation, (e) forest land, and (f) edge density.

Part 1--*Atlas*

Part 1--Atlas

The layout of the species pages was designed to portray maximum information about the species, using minimum space. For each species, facing pages present data and charts on key variables associated with the species distribution now and under a couple of global climate change scenarios, and a series of color maps related to current and possible future distribution according to one general circulation model (GCM) scenario. Each species is keyed to the Life History section, which starts on page 175. The following sections provide detailed explanations of data included on the facing pages. A foldout guide (inside back cover) presents abbreviated guidelines on how to read and use the atlas.

Current Status and Rank

The current status and rank (among 80 species) presents the amount and rank of area and importance for each species, as calculated in a geographic information system.
Area, FIA: total area occupied by the species, according to FIA data (using summed county data). Rank shows the importance relative to other species in the 80-species data set.
Area, Little: total area occupied by the species, according to Little's maps (1971, 1977).
IV (importance value), average: average IV for the species across its distribution, according to FIA data.
SArea x IV: the sum of area of each county times its average IV; this number is an indication of its overall importance.

Potential Change from Climate Change

As detailed in Iverson and Prasad (1998) and Prasad and Iverson (1997), we have estimated the percent changes potentially possible in a 2xCO_2 climate for two GCMs: the Goddard Institute of Space Studies (GISS) (Hansen et al. 1988) and the Geophysical Fluid Dynamics Laboratory (GFDL) (Wetherald and Manabe 1988). We also present data for these and three other GCMs on our web site (see inside cover for URL). The doubled CO_2 is likely to occur within 100 years, unless drastic global efforts are made to curtail CO_2 emissions. We emphasize that these are potential changes in importance values (IV) due to possible future climate change scenarios. We have assumed that the species will reach its potential distribution and that no barriers to migration will occur. In reality, migration will occur more slowly in highly fragmented environments (Schwartz 1992, 1996; Iverson et al. 1999).
Weighted IV, %: reflects the potential change (%) in area-weighted IV, first for the GISS, then GFDL GCM scenarios. As such, it reflects both change in area and change in IV for the species. It is calculated by multiplying the area of each county by the IV for that county, summing those values across all counties, and calculating percent change from current to GCM scenario scores.
Area, %: potential change in area for GISS and GFDL GCM scenarios.
Optimal latitude, km: reflects change in the optimum IV latitudinally. Most species show a northward shift in the optimum following climate change. Several steps were required to calculate the optimum. First, the country was subdivided into a grid of 10-x 10-km cells, which included 277 rows of data for the eastern United States. The relative IVs were calculated for each row (total IV/total area in row), and the overall distribution by row was statistically analyzed. The optimal latitude was then calculated as the mean of the interquartile range (all the points falling between the 25^{th} percentile and the 75^{th} percentile); so, we take the mean of the bulk of the data without including outliers. The change is calculated (in km) by subtracting the predicted optimal latitude from the optimum predicted by the GCM scenario; if the remainder is positive, a northward migration is projected.

FIA Distributional Summaries

To best reflect the statistical distribution for each variable of the actual FIA data, a table was generated with statistics depicting the shape of the distribution curve. For each variable, we report the absolute minimum, the first quartile (25^{th} percentile) of data, the mean, the median (second quartile or 50^{th} percentile of data), the third quartile (75^{th} percentile), the absolute maximum data point, and the rank of this species' median relative to the other 79 for this variable. So, the median is the midpoint of the data, and can be coarsely construed as the optimum point for the species. For example, in the distribution curves for *Populus grandidentata* and *Pinus taeda,* median January temperature of -6.0 and 5.9 □C could be interpreted as optimal conditions with respect to this variable, and they rank 73^{rd} and 11^{th} for all species in median January temperature (Fig. 2).

For each species, the following variables have been assessed from the FIA data:
Number of counties: the total number of counties in which the species has been recorded, according to FIA data.
Diameter, cm: the average diameter for the species across each FIA plot, assessed on a per plot basis. The number of plots that occur in the number of counties given in the above field is also given.
Growth Rate, cm^2 basal area/yr: based on FIA remeasurement plots only (a subset of the total number of plots), this variable is calculated as the difference between basal areas (per plot basis) for each species measured on plots at two sampling intervals. Usually, the time between measurements is about 10 years. To remove plots that show a negative growth (that is, the plot was harvested), only plots with positive growth were included in the distribution curve.
Annual Temperature, □C: average annual temperature for the counties occupied by the species. Data from U.S. Environmental Protection Agency (1993).
January Temperature, □C: average January temperature for the counties occupied by the species. Data from U.S. Environmental Protection Agency (1993).
Precipitation, mm: average annual precipitation for the counties occupied by the species. Data from U.S. Environmental Protection Agency (1993).
Potential Evapotranspiration, mm/month: average monthly potential evapotranspiration for the counties occupied by the species. Data from U.S. Environmental Protection Agency (1993).

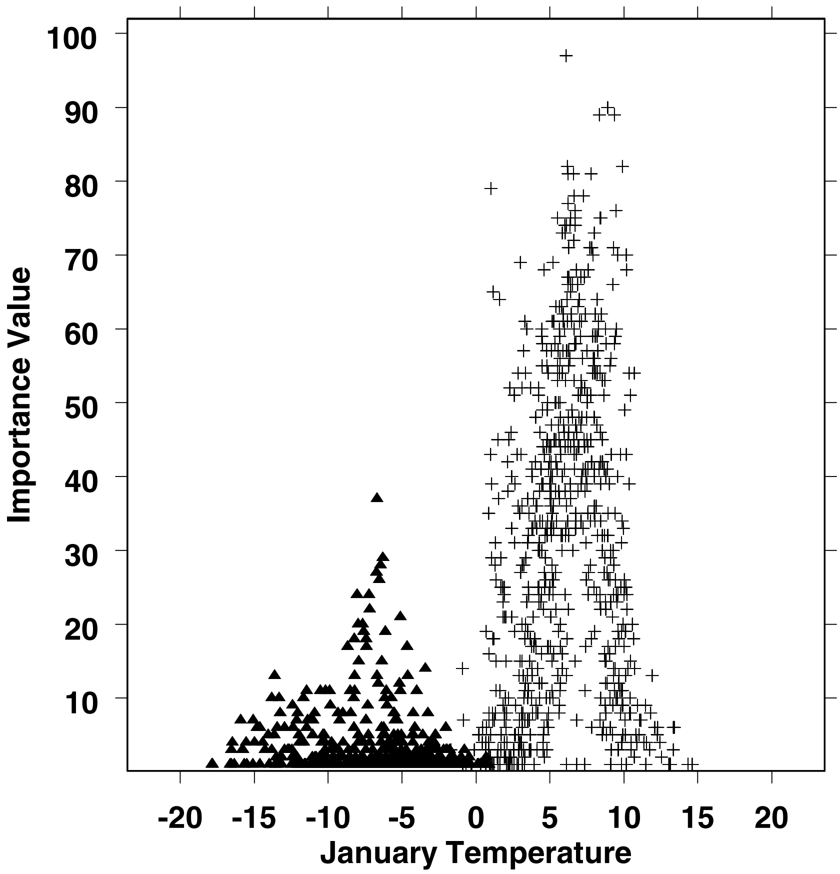

Figure 2.–Distribution of *Populus grandidentata* (triangles) and *Pinus taeda* (plus signs) importance values by January temperature.

Maximum Elevation, m: average maximum elevation for the counties occupied by the species. Data from U.S. Geological Survey (USGS) 1:250,000 Digital Elevation Model (DEM) files (U.S. Geological Survey 1990, ongoing).

Slope, percent: average percent slope for the counties occupied by the species. Data from the State Soil Geographic Data Base (STATSGO), developed by the U.S. Natural Resource Conservation Service on 1:250,00 scale maps (Soil Conservation Service 1991); processing included calculating an area-weighted average for each map unit based on the percent composition for each soil series in the map unit, and then calculating another area-weighted average for all map units within each county (Iverson et al. 1996).

pH: average pH for soils in the counties occupied by the species. Data are from STATSGO (Soil Conservation Service 1991), and because tabular data are reported by layer and soil series, three weighted averages were needed to calculate a county average (Iverson et al. 1996). First, 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. Then, area-weighted averages were calculated for map unit and county as described for slope.

Permeability, cm/hr: the property of the soil that permits transmission of water through the soil, and is related to hydraulic conductivity of the soil. The finer the material (less porous), the slower the permeability. The data are processed from STATSGO, as discussed above for pH.

Organic Matter, percent: the percentage of organic matter in the surface layer of the soil. Data are from STATSGO, and calculated as for slope.

Clay, percent: the percentage of clay in the soil column to a depth of 60 inches (152 cm) or the depth to bedrock. Data are from STATSGO, and calculated as for pH.

Water-Holding Capacity, cm/152 cm: average available water-holding capacity in the soil to bedrock or 152 cm (60 inches), whichever comes first. Data were calculated by summing the available water-holding capacity for each layer in the soil horizon, as described for pH.

Graphs of Climate, Landform, and Soil

The climate, landform, and soil graphs show the distribution of species IV by precipitation and average temperature for climate, by maximum elevation and slope for landform, and by pH and permeability for soil. The particular variables are explained in the previous section. The entire envelope for all the species (the domain of our study area) is shown in gray (which is the same for all species). The various shades inside reflect the IV of the species, with darker shades indicating higher importance within the total space. All species are plotted with the same axes so that direct comparisons among species can be made. For example, *Pinus virginiana* (Virginia pine) prefers low pH soils and high rainfall relative to many other species (page 104). It should be noted that for species bounding the northern border of the United States, the range of ecological space would likely extend beyond that portrayed here. In addition, some species have artificial boundaries imposed by variations in taxonomic definitions used by the four FIA units (Hansen et al. 1992, discussed in the following "Maps" section). In these instances, the ecological space and resulting regression tree models would reflect these artificial boundaries as well, and should be interpreted accordingly.

Tree Diagram

The tree diagram is the output from the RTA (Clark and Pergibon 1992), and is the basis for prediction of current and potential future distributions of IV. The basis of the diagram is explained in the RTA section (Appendix C). By following a branch and the current or predicted future variables for the county, one can predict the importance value for the species (shown at the terminal node of the branch, along with the number of counties for that branch and the class for mapping). The bracketed numbers at the bottom of the diagram are links to the legend for the map of geographic predictors, center left on the facing page. The map can be interpreted by tracing the tree diagram as explained above. Variables that operate at large scales are depicted at the top of the tree diagram (for example, broad climatic patterns), whereas lower branches more often determine the local variations in distribution. However, because the data are analyzed at the county level of resolution, the models will not capture environmental drivers that operate at a very fine scale (for example, individual slopes or valley bottoms).

For example with southern red oak (*Q. falcata* var. *falcata*, page 120), there is essentially no representation of the species in 1,222 counties with an average January temperature below 0.34°C. In this example, the maximum IV (8.0) is found in 94 counties that have a January temperature > 0.34°C, an average slope in the county exceeding 2.3 percent, average total water-holding capacity exceeding 7.7 cm, and a maximum elevation > 160 m. The northern band of southern red oak presence is found where January temperature is less than 3.2°C, indicating that temperature may be the key factor regulating the northern boundary of the species.

Variables used in the tree diagram, along with the abbreviations and two measures evaluating the relative importance of each variable in predicting distribution for all 80 species, are presented in Table 1.

The R^2 value gives an indication of the strength of the regresssion tree model. As R^2 values approach 1.00, the model becomes more robust at predicting importance values for the species.

Maps

Maps for each species show the spatial distribution, by county, of six forms of data: current FIA, modeled current, predicted GISS, GISS difference, geographic predictors, and potential shifts. The gray-shaded areas on the maps indicate that no FIA data were available, so no data are reported for those counties. Several reasons account for no county data: (1) no data available for any tree species for those counties; this occurs for many counties in the Prairie States, especially Oklahoma and Texas along with a spattering of counties elsewhere in the western part of the region, and in the southern tip of Florida; (2) one or more of the four FIA units (northeastern, north central, southeast, southern) collecting the FIA data did not report the species in their data base, most likely because it was not present in the region -- this occurs for several distinctly northern (for example, *Betula papyrifera, Populus tremuloides*) or distinctly southern (for example, *Pinus elliotti, Pinus palustris*) species; or (3) one or more of the FIA units do not recognize a particular species name as present in the unit, even though it undoubtedly is present but called something else. This occurs especially in the *Carya* genus, where some units lump species into *Carya* spp., while others identify them to species. Unfortunately, when viewing the maps it is not always easy to distinguish the cause of no county data, especially between the second and third cause. If the species distribution is wholly encompassed with some white (IV < 1.0) zones around the range and outside the gray zone, it likely is because the species is not present in the gray zone -- the second cause. If the species distribution abruptly ends at the gray boundary, it is probably a taxonomic confusion -- the third cause. All maps were produced using Arc/Info (Environmental Systems Research Institute 1993).

Current FIA—These maps show actual recorded distributions (IV, on a scale of 0 to 200) according to the Forest Inventory Analysis program of the USDA Forest Service. Data are based on 100,000+ plots and nearly 3 million trees. FIA data are taken from the Eastwide Forest Inventory Data Base (Hansen et al. 1992). A summary of the number of plots, forest area, and dates of included inventories for each state are presented in Table 2 (Appendix A).

Also shown here and on the modeled current and predicted GISS maps, in bold outline, is the distribution according to Little (1971, 1977). These boundaries were generated from USDA Forest Service data available at that time, herbaria records, and expert opinion by Elbert Little and others. Maps were digitized in our laboratory. Little's maps may give a more complete geographic range (presence/absence) of the species than the FIA maps because FIA uses a sampling scheme that could miss sparse species in some counties. However, Little's map boundaries might also overestimate total species ranges, as 'islands' of species absence may be missed by the general range delineations. Little's data are also older.

Modeled Current—These maps show current distributions modeled from the RTA. The map is simply a spatial representation of the output from the RTA. The majority of nodes for this output are from the tree diagram presented previously; additional nodes (up to 20 total nodes) are not shown in the diagram but are used in our analysis to create the current distribution maps. See RTA (Appendix C) for an explanation of the modeling process, or refer to Iverson and Prasad (1998).

Predicted GISS—These maps show predicted potential future species distribution, using the GISS GCM and the tree diagram shown previously. It should be emphasized that this GISS scenario (Wetherald and Manabe 1988) is only one of a multiple set of scenarios and that the intention here is to give an example output scenario rather than absolutely predict future distributions. Outputs for four additional scenarios are presented on our website (see inside cover for URL). Predicted GISS maps indicate the sensitivity of the species to its current environment and also show which species might require more migration to persist in a globally changed climate.

GISS Difference—These maps present the numeric difference in each cell between Modeled Current and Predicted GISS abundances. The scores indicate the changes predicted in IV. Scores close to zero indicate that no changes in abundance are predicted.

Geographic Predictors—As mentioned in the "Tree Diagram" section, these maps are tied to the tree diagram, and show the main variables that drive the distribution of the species. Follow the branches of the tree diagram to the class number at the bottom of each node to match the legend for this map. This output illustrates a principle advantage of the RTA approach, because it shows how different variables can drive the IV of a species in different parts of a species distribution.

Potential Shifts—These maps display the modeled current distribution, along with predicted potential future distribution (using the GISS scenario) and the overlap where each species is now and is projected to be present in the future.

Species listed by scientific names

Abies balsamea
Acer negundo
Acer pensylvanicum
Acer rubrum
Acer saccharinum
Acer saccharum
Betula alleghaniensis
Betula lenta
Betula papyrifera
Carpinus caroliniana
Carya cordiformis
Carya glabra
Carya ovata
Carya spp.
Carya tomentosa
Celtis laevigata
Celtis occidentalis
Cercis canadensis
Cornus florida
Crataegus spp.
Diospyros virginiana
Fagus grandifolia
Fraxinus americana
Fraxinus nigra
Fraxinus pennsylvanica
Fraxinus spp.
Gleditsia triacanthos
Ilex opaca
Juglans nigra
Juniperus virginiana
Liquidambar styraciflua
Liriodendron tulipifera
Maclura pomifera
Magnolia virginiana
Morus rubra
Nyssa aquatica
Nyssa sylvatica var. biflora
Nyssa sylvatica var. sylvatica
Ostrya virginiana
Oxydendrum arboreum
Pinus echinata
Pinus elliottii
Pinus palustris
Pinus resinosa
Pinus strobus
Pinus taeda
Pinus virginiana
Platanus occidentalis
Populus deltoides
Populus grandidentata
Populus tremuloides
Prunus serotina
Quercus alba
Quercus coccinea
Quercus falcata var. falcata
Quercus falcata var. pagodifolia
Quercus laurifolia
Quercus macrocarpa
Quercus marilandica
Quercus muehlenbergii
Quercus nigra
Quercus palustris
Quercus phellos
Quercus prinus
Quercus rubra
Quercus stellata
Quercus velutina
Robinia pseudoacacia
Salix nigra
Salix spp.
Sassafras albidum
Taxodium distichum var. distichum
Taxodium distichum var. nutans
Thuja occidentalis
Tilia americana
Tsuga canadensis
Ulmus alata
Ulmus americana
Ulmus rubra
Ulmus spp.

Part 2--*Life History*

Part 2--Life History

In this section, we present life history information about each species. Sources are many, and are listed at the end of this section. The intention is to provide concise, synthesized information about many, but not all, ecological aspects of the species. We cannot, and do not, intend to present exhaustive information for each species, but rather a 'broad brush' approach so that comparative and categorical analyses can be performed. We refer you to the Silvics of North America manuals (Burns and Honkala 1990a,b) for more detailed information on damaging agents as well as extensive text and citations on many of the variables listed below. We also refer you to the USDA Forest Service Fire Effects Information System data base (Fischer, ongoing) which contains a large array of basic as well as fire-related information about nearly all tree species in the United States, and to the many data bases being brought online through the National Biological Information Infrastructure (U.S. Geological Survey, ongoing).

Data presented for each species are:
Family: botanical family of the species.
Guild: grouping of species according to tree regeneration capabilities.
Functional Lifeform: relates to structural size, form, and seasonal nature of tree species.
Ecological Role: short explanation of habitat for the species.
Lifespan, yrs (typical/max): longevity under typical or ideal conditions.
Shade Tolerance: capacity to survive and grow in the understory [very tolerant, tolerant, intermediate, intolerant, or very intolerant].
Height, m: typical heights achieved under forested conditions.
Canopy tree: species usually occupies a position in the main crown canopy [yes, no (understory tree)].
Pollination Agent: major vector of pollination [wind, insects].
Seeding, yrs (begins/optimal/declines): age when the species, under good conditions, starts to produce viable seeds, reaches its optimum, and begins to decline in seed production.
Mast Frequency, yrs: frequency of good seed years (large seed crops).
New Cohorts Source: possible sources of new plants [seeds, sprouts (seedling sprouts or stump sprouts), root suckers].
Flowering Dates: season of flowering [early spring (~March 1-April 15), late spring (April 15-May 31), or summer (June-August)].
Flowers/Cones Damaged by Frost: flowers or cones can be damaged by frost [yes, no].
Seedfall Begins: time when ripe seed starts to be dispersed [spring-summer, early fall (September-October), or late fall-winter (November-February)].
Seed Banking: time that seed can survive in the seed bank [seasonal, < 1 month; seasonal, up to 1 year; short-term persistent, 1-10 years; persistent, 10+ years].
Cold Stratification Required: does the seed need cold stratification before it can germinate [yes, no].
Seed Type/Dispersal Distance/Agent: type of seed (or fruit), its typical dispersal distance, and common dispersal agent(s) [nuts and pods, to 50 m, gravity and animals; small nonwinged, to 50 m, wind and gravity; berries and drupes, to 100 m, birds and gravity; winged seeds, to 100 m, wind; winged seeds, 100-200 m, wind; plumed seeds, > 200 m, wind].
Season of Germination: season when seeds typically germinate [spring, summer, fall].
Seedling Rooting System: form of seedling/juvenile root system [taproot; variable (depends on soil type and moisture levels); shallow-spreading].
Sprouting: possible modes of vegetative reproduction [seedling sprouts, stump sprouts, root suckers, stem/rhizome sprouts, layerings].
Establishment Seedbed Preferences:
Soil: substrate needed to germinate [bare mineral soil; litter/humus/moss; or variable].
Light: seedbed light environment suitable for germination [open conditions only — high light levels; overstory shade — variable light levels]. For some species, the seeds can germinate, even germinate better, under shade, but are intolerant of shade to survive and grow. As such, the species may be listed as intolerant to shade, yet prefer shade for germination (for example, *Betula papyrifera, Fraxinus nigra, Quercus nigra, Pinus taeda*).
Moisture: moisture level that supports germination and establishment [wet required, moist required, moisture neutral].
Temperature: soil temperature required for germination [cool/cold soil required, warm soil required, temperature neutral].
Disturbance Response: effects of fire, air pollution, drought, insects and disease on the species. This text focuses primarily on nonbiological disturbance agents (fire, weather, and to the extent available, air pollution), but also considers some particularly devastating (mostly exotic) pests and disease. Special attention has been given to response to fire, as this type of synopsis has not previously been published for Eastern species.

Abies balsamea

Balsam Fir

Pinacaea — *Map Section, Page 12*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: small to medium-size evergreen tree
Ecological Role: grows on a wide range of sites from gravelly sands to peat swamps; can establish under dense canopies and quickly responds to release
Lifespan, yrs (typical/max): 80/200
Shade Tolerance: very tolerant
Height, m: 12-27
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/30/70
Mast Frequency, yrs: 2-4
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring — early summer
Seedling Rooting System: heavy central root
Sprouting: occasional layering
Establishment Seedbed Preferences
  Substrate: mineral soil or shallow litter
  Light: overstory shade
  Moisture: moist required
  Temperature: neutral
Disturbance Response

Fire: Balsam fir increases in the absence of fire. Fires are usually high-intensity crown fires, occurring at intervals of several centuries. Balsam fir is the least fire-resistant conifer in the northeastern United States. Most fires kill trees and destroy seeds. The bark is thin, resinous, easily ignitable and roots are shallow. Seeds have no endosperm to protect them from high temperatures. Balsam fir is generally slow to reestablish after fire, relying on rare survivors found in protected pockets within the burn, or trees from adjacent unburned areas to provide seed. It is usually rare or absent for the first 30 to 50 years after fire, but gradually establishes under the canopy of other tree species.

Weather: Balsam fir is susceptible to windthrow, especially older trees growing on wet, shallow soils.

Air Pollution: Balsam fir is intermediate in sensitivity to sulphur dioxide and tolerant to ozone.

Exotics: An exotic insect introduced from Europe or Asia around 1900, the balsam woolly adelgid (*Adelges piceae*) is decimating balsam fir populations, particularly in the southern part of its range where the insect is not controlled by low winter temperatures.

Acer negundo

Boxelder

Aceraceae — *Map Section, Page 14*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: pioneer on disturbed, open sites; gradually replaces early, shade-intolerant colonizers on river flood-plains and moist uplands
Lifespan, yrs (typical/max): 75/100
Shade Tolerance: tolerant
Height, m: 12-15
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 8/30/75
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: taproot and laterals
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
  Substrate: variable
  Light: overstory shade
  Moisture: moist required
  Temperature: neutral
Disturbance Response

Fire: Boxelder grows on moist bottomland sites where fire rarely occurs. Because its bark is thin, boxelder is susceptible to topkilling from fire, but sprouts readily from the root crown or caudex. Although the relationship between fire and seedling production is unknown, boxelder is a pioneer species that produces copious numbers of wind-dispersed seed and would likely colonize newly burned sites rapidly. It is likely to increase in density following fire.

Weather: Boxelder is resistant to drought and cold, but ice and wind damage is common in older trees.

Air Pollution: The variety *A. negundo interius* (Manitoba maple) is sensitive to sulphur dioxide. Boxelder is sensitive to intermediate in sensitivity to ozone, and is sensitive to hydrogen fluoride.

Acer pensylvanicum

Striped Maple

Aceraceae — *Map Section, Page 16*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: large shrub or small deciduous tree
Ecological Role: found on moist well-drained uplands; survives under heavy shade for many years and can rapidly

respond to release; also common in small forest openings
Lifespan, yrs (typical/max): 100/No Data
Shade Tolerance: very tolerant
Height, m: 9-15
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 11/No Data/100
Mast Frequency, yrs: No Data
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: shallow, spreading
Sprouting: occasional basal sprouting and layering
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Fire is probably rare on the moist upland sites where striped maple commonly grows, occurring at intervals of decades to centuries. There is little information about the relationship of fire to this understory species, but it is apparently moderately resistant to low-intensity fires. However, crown fires in the overstory trees that result in partial openings in the forest canopy create ideal conditions for striped maple regeneration.

Acer rubrum
Red Maple
Aceraceae *Map Section, Page 18*

Guild: pioneer, spring-dispersed, moist-site tolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: common on a wide range of sites from mesic uplands to swampy lowlands; aggressively colonizes disturbed sites and also becomes established in a variety of understory conditions; responds rapidly to release
Lifespan, yrs (typical/max): 80/150
Shade Tolerance: tolerant
Height, m: 18-27
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 5/35/80
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late spring — early summer
Seed Banking: 1 yr +
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring — early summer
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Red maple is favored when fire is suppressed, and in many of the forests where it occurs it has increased in dominance dramatically during the past decades. The fire interval for red maple is long (many decades to centuries), and low-intensity surface fires are typical. A thin-barked species, red maple is susceptible to damage, topkill, and mortality from fire. Saplings are more susceptible than larger, thicker barked individuals. Fire effects vary according to season of burning; red maple is most susceptible in late spring to early summer. Topkilled seedlings and trees sprout vigorously and rapidly from dormant buds on the root crown. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind. This species may assume increased prominence after a single (unrepeated) fire. Prescribed fires, particularly multiple fires, have been used to control red maple but as trees become larger and bark thickens, they become more resistant.
Air Pollution: Red maple is tolerant to intermediate in sensitivity to sulphur dioxide and tolerant to ozone, but response varies among populations. Symptoms of foliar injury have been noted in areas of high ambient ozone. Seedlings of red maple exhibited reduced height growth under controlled fumigation with ozone.

Acer saccharinum
Silver Maple
Aceraceae *Map Section, Page 20*

Guild: pioneer, spring-dispersed, moist-site tolerant
Functional Lifeform: large deciduous tree
Ecological Role: a pioneer on floodplains, bottomlands, and other moist, well-drained sites; also reproduces under shade-intolerant hardwoods on moist sites; can withstand short periods of suppression
Lifespan, yrs (typical/max): 100/130
Shade Tolerance: tolerant
Height, m: 26-37
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 11/35/125
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late spring
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind, water
Season of Germination: spring — early summer
Seedling Rooting System: shallow, spreading
Sprouting: common

Establishment Seedbed Preferences

Substrate: mineral soil
Light: overstory shade
Moisture: moist required
Temperature: neutral

Disturbance Response

Fire: Silver maple grows on bottomland sites, where fire rarely occurs. It increases during long fire intervals. Silver maple is not well adapted to survive fire even though it sprouts after other disturbances. The relatively soft wood, thin bark, and tendency to rot allows it to succumb to fire-caused wounds. Its shallow roots are probably easily damaged by fire. It invades suitable sites where fire has been suppressed.

Weather: Silver maple seedlings are very tolerant of flooding. Silver maple is highly susceptible to ice damage.

Air Pollution: Silver maple is tolerant to intermediate in sensitivity to sulphur dioxide. It is rated by some as sensitive to ozone, but no symptoms of foliar injury were noted by others in areas of high ambient ozone. Seedlings of silver maple exhibited reduced height growth and biomass accumulation under controlled fumigation with ozone.

Acer saccharum

Sugar Maple

Aceraceae *Map Section, Page 22*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: large deciduous tree
Ecological Role: found on moist, well-drained, fertile sites; survives for long periods under heavy shade and responds well to release
Lifespan, yrs (typical/max): 300/400
Shade Tolerance: very tolerant
Height, m: 27-37
Canopy Tree: yes
Pollination Agent: insects and wind
Seeding, yrs (begins/optimal/declines): 25/40/200
Mast Frequency, yrs: 2-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: early spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common, occasional layerings

Establishment Seedbed Preferences

Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: cool

Disturbance Response

Fire: Sugar maple increases during long fire intervals; it has proliferated where fire has been suppressed and has invaded communities where fire was formerly frequent. In the mesic, closed-canopy forests where sugar maple grows, litter is usually moist and fires that occur are often low-intensity surface fires. However, damaging fires of moderate to high intensity can occur in dry autumns, after leaves have fallen. Sugar maple is considered to be fire-sensitive; its thin bark is easily damaged by even low-intensity surface fires. Large trees occasionally survive light fires and may exhibit visible fire scars. Sprouting is poor following fire, but seedlings occasionally sprout from the root crown. Postfire establishment occurs primarily through an abundance of wind-dispersed seed.

Weather: Sugar maple is extremely sensitive to flooding during the growing season, and susceptible to winter sunscald and glaze ice damage.

Air Pollution: Sugar maple is tolerant to ozone, sulphur dioxide, and hydrogen fluoride. Symptoms of foliar injury were noted in some areas of high ambient ozone, but not in others. Seedlings exhibited some reduced height growth, biomass accumulation, and photosynthesis rates under controlled fumigation with ozone. Genetically variable response to ozone fumigation was noted among individual seedlings.

Betula alleghaniensis

Yellow Birch

Betulaceae *Map Section, Page 24*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: common component of mesic, northern mixed hardwood forests; requires canopy openings for successful establishment and growth; gradually replaced by more tolerant species
Lifespan, yrs (typical/max): 150/300
Shade Tolerance: intermediate
Height, m: 20-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 30/40/70
Mast Frequency, yrs: 1-4
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged nutlet/ to 200 m/ wind
Season of Germination: late spring
Seedling Rooting System: variable
Sprouting: common

Establishment Seedbed Preferences

Substrate: mineral soil, moss or rotten wood
Light: open areas only
Moisture: moist required
Temperature: warm

Disturbance Response

Fire: Yellow birch thrives on disturbance; it is opportunistic with respect to fire (it increases after fire) but it is not fire-dependent. Usually occurring at intervals of several decades to centuries, fires are typically high-intensity surface or crown fires. A thin-barked species, yellow birch is sensitive to fire, and young trees rarely survive. Older trees may survive low-intensity fires. When wounded, surviving trees are highly susceptible to decay. Yellow birch sprouts poorly following topkill. Seed germination and seedling establishment are enhanced by fire, particularly fires that burn the leaf mat, expose mineral soil, and create canopy openings, but leave some mature trees as seed sources. Yellow birch frequently forms pure patches following fire. Prescribed fire has been used for yellow birch seedbed preparation.

Weather: Yellow birch is subject to windthrow on shallow, poorly drained soils. It is susceptible to damage from ice and heavy snow, and winter sunscald.

Air Pollution: Yellow birch is sensitive to sulphur dioxide. No difference was observed in seedlings fumigated with ozone under controlled conditions.

Betula lenta

Sweet Birch

Betulaceae *Map Section, Page 26*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on moist, well-drained soils; often a component of hardwood mixtures that developed under second-growth, old-field white pine; also may grow as advance regeneration in canopy openings or under hardwood stands with light to moderate crown densities
Lifespan, yrs (typical/max): 150/250
Shade Tolerance: intolerant
Height, m: 15-20
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 40/40/70
Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged nutlet/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: common
Establishment Seedbed Preferences
Substrate: humus, rotten wood, mineral soil
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Fire is probably rare (occurring at intervals of decades to centuries) on the moist upland sites where sweet birch commonly grows. Little information is known about the response of sweet birch to fire, but it would likely increase during long fire intervals. This extremely thin-barked species is susceptible to topkilling from fire. When wounded, surviving trees are highly susceptible to insects and decay. Germination is best under moist conditions and some shade, so establishment would likely occur only after low-intensity fire. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind.

Weather: Sweet birch is intermediate to resistant to glaze damage, but damaged crowns may provide entries for decay organisms and cause subsequent decline and death. It is intermediate in drought resistance.

Betula papyrifera

Paper Birch

Betulaceae *Map Section, Page 28*

Guild: opportunistic, short-lived intolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: pioneer on disturbed areas forming nearly pure stands; common associate in conifer-hardwood mixtures on cool, moist sites
Lifespan, yrs (typical/max): 100/140
Shade Tolerance: intolerant
Height, m: 12-21
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/40/70
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr.+
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: common; profuse on fire-damaged stems
Establishment Seedbed Preferences
Substrate: mineral soil or humus
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Paper birch is well adapted to disturbance and is opportunistic with respect to fire but it is not fire-dependent. In mixed stands, it burns at intervals of several decades and in pure stands, it burns only during unusually dry conditions at longer intervals. The bark of paper birch is both thin and highly flammable, which renders trees highly susceptible to topkilling. However, in trees <50 years old it sprouts from the root collar prolifically and vigorously. Paper birch is an abundant producer of lightweight, wind-dispersed seeds that readily germinate on mineral seedbeds created by fire. Prescribed fire has been used to prepare seedbeds for paper birch regeneration.

Weather: Paper birch stems are susceptible to breakage in high winds.

Air Pollution: Paper birch is sensitive to sulphur dioxide. No differences were observed in seedlings fumigated with ozone under controlled conditions.

Carpinus caroliniana
American Hornbeam (Musclewood)
Betulaceae *Map Section, Page 30*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: small deciduous tree
Ecological Role: found on rich, moist well-drained soils; seedlings readily establish in undisturbed forests and may persist for many years; shade tolerance declines with age and canopy openings are needed to maintain mature trees
Lifespan, yrs (typical/max): 100/150
Shade Tolerance: very tolerant
Height, m: 5-11
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/25/75
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nutlet with bract/ to 100 m/ birds, wind
Season of Germination: spring
Seedling Rooting System: No Data
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: American hornbeam grows on swampy sites, where fire rarely occurs. Fires burn at intervals of several decades, primarily during the dormant season. In some places, severe wildfires have eliminated this species, but fire has been observed to have no effect on its density elsewhere. American hornbeam is probably either topkilled or killed by most fires. After topkilling, it sprouts from adventitious buds in the root collar. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, birds, and other animals. Prescribed burning during very dry periods in the dormant season may be useful in controlling American hornbeam where it competes with other species.

Weather: American hornbeam is resistant to frost damage, and as the common name “musclewood” implies, is windfirm.

Carya cordiformis
Bitternut Hickory
Juglandaceae *Map Section, Page 32*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows on a wide range of sites from dry, gravelly uplands to moist flats; common associates include upland oaks, sugar maple, basswood, and many bottomland hardwoods; also found as an understory component in southern pine forests
Lifespan, yrs (typical/max): 175/200
Shade Tolerance: intermediate
Height, m: 15-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 30/50/175
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable, litter covered
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Bitternut hickory is broadly distributed and grows on a range of site types, but best on more mesic sites. Fires are probably unusual in bottomlands and usually occur only during prolonged droughts. Fires in the upland forests tend to be low- to moderate-intensity surface fires, occurring in the dormant season. When fires occur at short intervals, *Quercus* species have a competitive advantage over *Carya*. Longer-interval fires may promote hickory abundance. A thin-barked species, bitternut hickories of all sizes are susceptible to topkilling. When topkilled, bitternut hickory sprouts from the root crown, stump, or root suckers. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, water, birds, and other animals. Released hickory trees may develop a large crown and abundant nut crops, an important food source for wildlife.

Weather: Bitternut hickory is windfirm.

Carya glabra
Pignut Hickory
Juglandaceae *Map Section, Page 34*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows on dry ridgetops and dry-mesic uplands; common in oak-hickory and mixed hardwood forests and provides mast for many wildlife species
Lifespan, yrs (typical/max): 200/300
Shade Tolerance: intermediate; varies throughout range
Height, m: 15-27
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 30/75/200

Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable, litter covered
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Pignut hickory is broadly distributed and grows on a range of site types. Fires are infrequent on mesic sites and usually occur during prolonged droughts. On drier sites, fires tend to be low- to moderate-intensity surface fires, occurring in the dormant season. When fires occur at short intervals, *Quercus* species have a competitive advantage over *Carya*. Longer interval fires generally increase hickory abundance. A thin-barked species, pignut hickories of all sizes are susceptible to topkilling. Seedlings are particularly sensitive but larger, thicker barked trees are more resistant. When topkilled, pignut hickory sprouts from the root crown, stump, or root suckers. Hickories are susceptible to rot where the stem has been wounded. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, water, birds, and other animals. Released hickory trees may develop a large crown and abundant nut crops, an important food source for wildlife.

Weather: Pignut hickories are windfirm.

Air Pollution: No symptoms of foliar injury were noted in areas of high ambient ozone.

Carya ovata
Shagbark Hickory
Juglandaceae *Map Section, Page 36*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size deciduous tree
Ecological Role: grows on a range of sites from dry-mesic uplands to mesic coves and bottomlands; seedlings and saplings persist for many years in the understory and respond well to release
Lifespan, yrs (typical/max): 250/300
Shade Tolerance: tolerant
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 40/60/200
Mast Frequency, yrs: 1-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable, litter covered
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Shagbark hickory is broadly distributed and grows on a range of site types. Fires are less common on mesic sites and usually occur during prolonged droughts. On drier sites, fires tend to be low- to moderate-intensity surface fires, occurring in the dormant season. When fires occur at short intervals, *Quercus* species have a competitive advantage over *Carya*. Fire intervals of several decades promote hickory. A thin-barked species, shagbark hickories are susceptible to topkilling. Seedlings and saplings under 10 cm d.b.h. are particularly sensitive but larger, thicker barked trees are more resistant. When topkilled, shagbark hickory sprouts from the root crown, stump, or root suckers. Hickories are susceptible to rot where the stem has been wounded. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, water, birds, and other animals. Released hickory trees may develop a large crown and abundant nut crops, an important food source for wildlife.

Weather: Shagbark hickories are windfirm.

Carya spp.
Hickory
Juglandaceae *Map Section, Page 38*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: hickories occur in widely different habitats from moist flats to dry uplands; many withstand suppression and respond well if released; mature trees provide mast for wildlife
Lifespan, yrs (typical/max): 175-200/200-300
Shade Tolerance: intermediate to tolerant
Height, m: 15-25
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25-30/50-75/200
Mast Frequency, yrs: 1-5, varies with species
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, small mammals, birds or water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common

Establishment Seedbed Preferences

Substrate: variable, litter covered

Light: overstory shade

Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Hickories generally increase at fire intervals of several decades or more, but when fires occur at short intervals, *Quercus* species have a competitive advantage over *Carya*. Many hickories are broadly distributed and grow on a wide range of site types. Fires are probably unusual on mesic sites and usually occur during prolonged droughts. On drier sites, fires tend to be low- to moderate- intensity surface fires, occurring in the dormant season. Longer interval fires may promote hickory abundance. A thin-barked genus, hickories of all sizes are generally susceptible to topkilling. Seedlings are particularly sensitive but larger, thicker barked trees are more resistant. When topkilled, hickories sprout from the root crown, stump, or root suckers. Hickories are susceptible to rot where the stem has been wounded. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, water, birds, and other animals. Released hickory trees may develop a large crown and abundant nut crops, an important food source for wildlife.

Weather: Most hickories are windfirm.

Carya tomentosa

Mockernut Hickory

Juglandaceae *Map Section, Page 40*

Guild: persistent, large-seeded, advance growth dependent

Functional Lifeform: large deciduous tree

Ecological Role: grows on dry ridges and fertile uplands; occurs in oak-hickory and beech-maple forests and is found in pine-hardwood mixtures; withstands suppression and responds well when released; provides mast for many wildlife species

Lifespan, yrs (typical/max): 200/300

Shade Tolerance: intermediate

Height, m: 18-30

Canopy Tree: yes

Pollination Agent: wind

Seeding, yrs (begins/optimal/declines): 25/40/200

Mast Frequency, yrs: 2-3

New Cohorts Source: seeds or sprouts

Flowering Dates: late spring

Flowers/Cones Damaged by Frost: yes

Seedfall Begins: early fall

Seed Banking: up to 1 yr

Cold Stratification Required: yes

Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, birds, other animals

Season of Germination: spring

Seedling Rooting System: taproot

Sprouting: stump sprouts common

Establishment Seedbed Preferences

Substrate: variable, moist duff

Light: overstory shade

Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Mockernut hickory is broadly distributed over a range of site types, but it grows best on fertile uplands. Fires on mesic sites usually occur during prolonged droughts. On drier sites, fires usually occur in the dormant season and tend to be low- to moderate-intensity surface fires. When fires occur at short intervals, *Quercus* species have a competitive advantage over *Carya*. Longer interval fires may promote hickory abundance. A thin-barked species, mockernut hickories are susceptible to topkilling. Seedlings and saplings under 10 cm d.b.h. are particularly sensitive but larger, thicker barked trees are more resistant. When topkilled, mockernut hickory sprouts from the root crown, stump, or root suckers. Hickories are susceptible to rot where the stem has been wounded. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind, water, birds, and other animals. Released hickory trees may develop a large crown and abundant nut crops, an important food source for wildlife.

Weather: Mockernut hickories are windfirm. Seedlings are very susceptible to frost damage.

Celtis laevigata

Sugarberry

Ulmaceae *Map Section, Page 42*

Guild: opportunistic, fast-growing understory tolerant

Functional Lifeform: medium-size deciduous tree

Ecological Role: grows on a wide range of sites but is most common on bottomlands and deep, moist soils; establishes under bottomland hardwoods and rapidly responds to release

Lifespan, yrs (typical/max): 125/150

Shade Tolerance: tolerant

Height, m: 18-24

Canopy Tree: yes

Pollination Agent: wind

Seeding, yrs (begins/optimal/declines): 15/30/70

Mast Frequency, yrs: 1

New Cohorts Source: seeds or sprouts

Flowering Dates: early spring

Flowers/Cones Damaged by Frost: yes

Seedfall Begins: early fall

Seed Banking: No Data

Cold Stratification Required: yes

Seed Type/Dispersal Distance/Agent: drupe/ variable/ birds, water

Season of Germination: spring

Seedling Rooting System: shallow

Sprouting: common on small stems

Establishment Seedbed Preferences

Substrate: variable

Light: overstory shade

Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Sugarberry grows on bottomland sites where fire rarely occurs. It has invaded former grasslands where fire has been suppressed. A thin-barked species, sugarberry is sensitive to topkilling from fire. Low-intensity fires will kill or topkill seedlings and saplings, and topkill larger trees; intense fires may kill even the largest trees. Wounding by fire increases susceptibility to butt rot. Seedlings and saplings sprout from adventitious buds in the root collar. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by birds and other animals.

Weather: Ice damages sugarberry crowns, creating entryways for rot.

Air Pollution: Symptoms of foliar injury have been noted in areas of high ambient ozone.

Celtis occidentalis
Hackberry
Ulmaceae *Map Section, Page 44*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: common along stream banks and on moist, fertile bottomlands; also occurs on uplands and is drought resistant; establishes and persists under dense shade; rarely colonizes old fields
Lifespan, yrs (typical/max): 150/200
Shade Tolerance: intermediate
Height, m: 9-29
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/30/70
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ variable/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: common on small stems
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Hackberry increases where fire is suppressed. Though little direct information is available about the relationship between fire and this species, hackberry appears to be sensitive to topkilling and mortality from burning, and decays rapidly when wounded. Small trees may sprout from the root collar. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by wind or birds and other animals. In prairies where hackberry is invading, prescribed fire may be a useful tool in decreasing the density of hackberry and other hardwoods, and to restore grasslands.

Weather: Hackberry is tolerant of flooding and resistant to drought.

Air Pollution: No symptoms of foliar injury were noted in areas of high ambient ozone.

Cercis canadensis
Eastern Redbud
Leguminosae *Map Section, Page 46*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: small deciduous tree
Ecological Role: occasional understory component on moist, well-drained sites and fertile bottomlands; tolerates nutrient deficiencies but grows best when plant competition is limited
Lifespan, yrs (typical/max): 75/90
Shade Tolerance: tolerant
Height, m: 4-8
Canopy Tree: no
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 7/20/75
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: late fall — winter
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: pod/ variable/ wind, gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Eastern redbud increases where fire is suppressed, and is invading woodlands and former grasslands where fire was once frequent. However, redbud is also very resilient to fire. Though susceptible to topkilling, it vigorously sprouts from adventitious buds in the root collar and from root suckers. Few or no new seedlings establish on burned sites, particularly those undergoing repeated burning. Prescribed burning has been used to encourage redbud sprouting.

Weather: Redbud is intolerant of flooding.

Air Pollution: Redbud is intermediate in sensitivity to ozone and sulphur dioxide. Symptoms of foliar injury have been noted in areas of high ambient ozone and under fumigation with ozone.

Cornus florida
Flowering Dogwood
Cornaceae *Map Section, Page 48*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: small deciduous tree

Ecological Role: typical understory tree in a wide range of forest types; grows rapidly when young; older trees are slow-growing and very persistent
Lifespan, yrs (typical/max): No Data/125
Shade Tolerance: very tolerant
Height, m: 9-12
Canopy Tree: no
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 6/15/No Data
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ variable/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: stump sprouts and layerings common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Flowering dogwood is well adapted to occasional fire. In the forests where dogwood grows, fires are usually low to moderate in intensity, and generally burn during the dormant season. Frequent fires may reduce or eliminate flowering dogwood. Although a very thin-barked species that is susceptible to topkilling, it sprouts prolifically from the root collar and may increase in density on burned sites. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by birds or other animals.

Weather: Dogwood is intolerant of flooding and drought.

Air Pollution: Flowering dogwood is tolerant to sulphur dioxide. Symptoms of foliar injury have been noted in areas of high ambient ozone and after ozone fumigation.

Exotics: Dogwood anthracnose *(Discula destructiva)* is a disease of unknown origin, first reported in 1978. Leaf, twig, and branch infections lead to lethal stem infections. Both eastern and western dogwood species are susceptible to it, and it has spread widely.

Crataegus spp.
Hawthorn
Rosaceae *Map Section, Page 50*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: small deciduous tree
Ecological Role: common along woodland or stream margins often forming dense thickets that provide wildlife cover; also found on eroded sites and poor soils; readily colonizes disturbed openings and abandoned fields
Lifespan, yrs (typical/max): 40/No Data
Shade Tolerance: intolerant
Height, m: 4-12
Canopy Tree: no
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): No Data
Mast Frequency, yrs: No Data
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: pome/ variable/ birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common
Establishment Seedbed Preferences
Substrate: variable
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Air Pollution: Symptoms of foliar injury have been noted in areas of high ambient ozone.

Diospyros virginiana
Common Persimmon
Ebenaceae *Map Section, Page 52*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: grows on a wide range of sites from dry, infertile uplands to rich, alluvial bottoms; competes well under harsh growing conditions; colonizes abandoned fields but also establishes in the understory and may persist for many years
Lifespan, yrs (typical/max): 80/No Data
Shade Tolerance: very tolerant
Height, m: 9-24
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 10/25/50
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: berry/ to 50 m/ birds, other animals
Season of Germination: late spring
Seedling Rooting System: taproot
Sprouting: stump sprouts and roots suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Common persimmon is well adapted to occasional fire and is known to decrease with fire exclusion. In the forests where this species grows, fires are usually low to moderate in intensity, and generally burn during the dormant season. Although often topkilled by surface fires, common persimmon sprouts readily from adventitious buds in the root crown or from root suckers. Stem density may increase following low- to moderate-intensity surface fires. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by water, birds, and other animals. Periodic fires have been used to decrease common persimmon dominance by preventing it from reaching the overstory in southern pine forests.

Weather: Young persimmon trees are susceptible to prolonged flooding.

Air Pollution: Symptoms of foliar injury have been noted on persimmon trees in areas of high ambient ozone.

Fagus grandifolia
American Beech
Fagaceae *Map Section, Page 54*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows on well-drained, coarse-textured soils and on some poorly drained sites; frequent associate of sugar maple but is common in many mixed-species hardwood stands; extremely tolerant of understory conditions and persists in subdominant positions for many years
Lifespan, yrs (typical/max): 300/400
Shade Tolerance: very tolerant
Height, m: 18-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 40/60/300
Mast Frequency, yrs: 3-8
New Cohorts Source: root suckers
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late fall — winter
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: root suckers and sprouts on young stems common
Establishment Seedbed Preferences
Substrate: mineral soil or leaf litter
Light: overstory shade required
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: At long fire intervals, American beech frequently becomes a dominant species in mixed deciduous forests; beech dominance is increasing in forests where fire has been suppressed. A thin-barked species with shallow roots, it is highly vulnerable to injury by even low-intensity fires. Seedlings and saplings are particularly susceptible. On surviving large trees, fire-caused wounds may be an entry point for fungi. Postfire colonization of beech depends on the number of surviving root suckers and on stump sprouting. Seedling establishment may occur from surviving trees onsite or from offsite seeds carried by birds and other animals.

Weather: Beech is highly intolerant of floods during the growing season. It is susceptible to winter sunscald and late spring frosts and to frost-cracking in cold winters, particularly during drought conditions. It is moderately susceptible to glaze-storm damage.

Air Pollution: No symptoms of foliar injury have been noted in beech trees growing in areas of high ambient ozone.

Exotics: Beech bark disease is spread by an exotic insect, the beech scale insect (*Cryptococcus fagisuga Lind.*). Once infested, pathogenic fungi of the genus *Nectria* (one exotic, one native) carried by the insect invade bark tissues and kill the tree. Introduced to Nova Scotia around 1890, it has spread throughout New England. Existing infestations are reduced and new ones are minimized by extreme cold winter temperatures and heavy autumn precipitation. Some trees are resistant to infestation.

Fraxinus americana
White Ash
Oleaceae *Map Section, Page 56*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: large deciduous tree
Ecological Role: colonizes fertile old fields and large forest openings; grows best on moist, well-drained soils and is common in many mixed hardwood forest types; becomes less shade tolerant with age but persists as a subdominant and responds well to release
Lifespan, yrs (typical/max): 260/300
Shade Tolerance: intermediate
Height, m: 24-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/40/125
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: White ash commonly grows on moist upland sites where fire is probably infrequent, occurring at intervals of several decades to centuries. Although white ash is highly susceptible to topkilling from fire, it readily sprouts from the root crown and may actually increase in density. Larger trees are moderately susceptible to fire-caused wounding and infestation by insects and decay organisms. After topkilling, it sprouts from the root crown or caudex. Seedling establishment may occur 2 years after the fire from seeds of surviving trees onsite or from offsite seeds carried by wind.

Weather: White ash has some tolerance to short-term flooding.

Air Pollution: White ash is sensitive to ozone. Symptoms of foliar injury have been noted in areas of high ambient ozone. White ash seedlings exhibited reduced biomass accumulation under controlled fumigation with ozone.

Fraxinus nigra
Black Ash
Oleaceae *Map Section, Page 58*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on muck soils along streams and in poorly drained areas; common associate of American elm, red maple, and northern white-cedar; on moist but well-drained sites it is part of a transitional type that is replaced by northern hardwoods
Lifespan, yrs (typical/max): 150/200
Shade Tolerance: intolerant
Height, m: 18-21
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): No Data
Mast Frequency, yrs: 4
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: In the swampy woodlands where black ash commonly grows, fire is infrequent, occurring at intervals of several decades to centuries. Trees are topkilled by moderate-intensity fires, and they sprout from the adventitious buds on the root crown or from root suckers. Surviving, wounded trees are susceptible to rot. Seedling establishment probably occurs 2 years after fire from seeds of surviving trees onsite or from offsite seeds carried by wind.

Weather: Black ash is probably tolerant of flooding.

Air Pollution: Black ash had variable ratings (tolerant to sensitive) in sensitivity to sulphur dioxide. It is sensitive to ozone. Symptoms of foliar injury have been noted in areas of high ambient ozone, and seedlings exhibited reduced biomass accumulation under controlled fumigation with ozone.

Fraxinus pennsylvanica
Green Ash
Oleaceae *Map Section, Page 60*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: grows best on fertile, moist well-drained soils along streams and in bottomlands; succeeds shade-intolerant pioneers and withstands understory conditions for many years
Lifespan, yrs (typical/max): 125/150
Shade Tolerance: tolerant, but varies throughout its range
Height, m: 14-17
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/40/125
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: seedling and stump sprouts (from small stems) common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Green ash is well adapted to occasional fire. It is tolerant of dormant-season low-intensity fires. Green ash communities have shown an increase in biomass, density, and cover when burned. It is thin-barked and readily topkilled by low- to moderate-intensity surface fires, and it sprouts prolifically from adventitious buds in the root crown or from root suckers. Seedling establishment probably occurs within 2 years after the fire from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed burning has been used to stimulate regrowth in older stands, but is not recommended in bottomland stands where it is grown for timber, and where decay from fire-caused wounds might reduce wood value.

Weather: Green ash is extremely tolerant of flooding.

Air Pollution: Green ash has had variable ratings (tolerant to sensitive) to sulphur dioxide. It is sensitive to ozone and intermediate in sensitivity to hydrogen fluoride. Variable foliar symptoms to high ambient ozone have been noted (none to some). Seedlings exhibited reduced height growth and biomass accumulation under controlled fumigation with ozone.

Fraxinus spp.
Ash
Oleaceae *Map Section, Page 62*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: found on a range of sites from moist, well-drained soils to poorly drained flats and swamp margins; often a significant component of mixed hardwood forests on upland sites but may occur as scattered individuals in bottomland forests; generally becomes less shade tolerant with age; often persists as a subdominant
Lifespan, yrs (typical/max): 125-250/150-300
Shade Tolerance: intermediate
Height, m: 18-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10-20/40/125
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: 1yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
  Substrate: variable
  Light: overstory shade
  Moisture: moist required
  Temperature: neutral
Disturbance Response
  Fire: Most ash populations will tolerate occasional fire. Although they have thin bark and are readily topkilled by fire, they generally sprout prolifically from the root crown or root sucker. Seedling establishment probably occurs 2 years after the fire from seeds of surviving trees onsite or from offsite seeds carried by wind.
  Weather: Most ash species are tolerant of flooding.

Gleditsia triacanthos
Honeylocust
Leguminosae *Map Section, Page 64*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: large deciduous tree
Ecological Role: common in moist, fertile bottomlands, old fields and open woodlands; withstands flooding and also is drought tolerant
Lifespan, yrs (typical/max): 125/150
Shade Tolerance: intolerant
Height, m: 21-40
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 10/25/75
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: no, impermeable seed coat
Seed Type/Dispersal Distance/Agent: pod/ to 50 m/ gravity
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
  Substrate: variable
  Light: open areas only
  Moisture: moist required
  Temperature: neutral
Disturbance Response
  Fire: Honeylocust increases when fire is suppressed. It seems to be excluded from prairies by frequent fire, and expands where fire is excluded. Alternatively, longer interval, high-intensity fires may open up canopies in bottomlands, providing regeneration sites. A thin-barked species, honeylocust is easily topkilled by fire, but it sprouts from adventitious buds in the root crown. Periodic, short-interval fires may be useful in controlling invasion of honeylocust into grasslands.
  Weather: Honeylocust is considered to be windfirm and resistant to ice damage.
  Air Pollution: Honeylocust is sensitive to ozone.

Ilex opaca
American Holly
Aquifoliaceae *Map Section, Page 66*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: small evergreen tree
Ecological Role: grows best on moist, slightly acid well-drained sites, but survives on sandy coastal soils or gravelly inland sites
Lifespan, yrs (typical/max): 100/150
Shade Tolerance: very tolerant
Height, m: 9-15
Canopy Tree: no
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 5/20/100
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: fruit ripens by late fall, remains on tree until spring
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ variable/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot with many laterals

Sprouting: common on young stems
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: American holly increases when fire is suppressed. Fire easily topkills American holly; its thin bark is easily injured by fire and the evergreen foliage is killed. Even large trees may be topkilled by low-intensity surface fires. American holly sprouts from the root crown, but short-interval fires (for example, three annual) can nearly eliminate it from a stand. Seedling establishment may occur in the second or third year after fire from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed fire has been used to eliminate seedlings and sprouts, particularly in pine stands.

Weather: American holly is intolerant of flooding in the growing season.

Air Pollution: American holly is tolerant of ozone.

Juglans nigra
Black Walnut
Juglandaceae *Map Section, Page 68*

Guild: opportunistic, long-lived intolerant
Functional Lifeform: large deciduous tree
Ecological Role: grows best on deep, well-drained fertile soils and occurs as an occasional tree in mesic and dry-mesic forests; grown in plantations for highly valued wood
Lifespan, yrs (typical/max): 150/250
Shade Tolerance: intolerant
Height, m: 30-37
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 6/30/130
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: possible
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut/ to 50 m/ gravity, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Black walnut trees are well adapted to periodic fire. Although most small black walnut trees are topkilled by fire, trees <20 to 30 years old will usually sprout from the root crown. Older trees usually survive the low- to moderate-intensity dormant-season surface fires common in the forests where black walnut grows. These trees have thick bark and naturally durable heartwood that make them relatively resistant to damage and decay. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by water, birds, and other animals.

Weather. Black walnut is moderately tolerant of flooding. It is susceptible to late spring frosts and freezing injury when dormancy is broken in late winter warming periods.

Air Pollution: Black walnut is tolerant of ozone and intermediate in sensitivity to hydrogen fluoride. No symptoms of foliar injury were noted in areas of high ambient ozone.

Juniperus virginiana
Eastern Redcedar
Cupressaceae *Map Section, Page 70*

Guild: pioneer, dry-site intolerant
Functional Lifeform: small to medium-size evergreen conifer
Ecological Role: rapidly invades abandoned fields and grows well on a wide range of soils; usually replaced by hardwoods except on poor sites or thin soils where competition is limited
Lifespan, yrs (typical/max): 150/300
Shade Tolerance: intolerant
Height, m: 12-18
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/25/125
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early spring
Seed Banking: 2-3 yrs
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: berrylike cone/ to 100 m/ gravity, birds
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: does not sprout
Establishment Seedbed Preferences
Substrate: mineral soil
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Eastern redcedar is highly sensitive to fire and is unable to persist on sites that burn more often than every 20 years. It increases in the absence of fire. Historically, eastern redcedar was restricted to sites that were protected from fire by topoedaphic factors and insufficient fuels. Since the fire suppression and widespread grazing that followed Euro-American settlement, eastern redcedar has invaded uplands and prairies. Prescribed burning has been used to control it. Eastern redcedar bark is very thin, and its fibrous roots lie near the surface. Its foliage is highly flammable and when ignited, crown fires are common. Seedlings and saplings are usually killed by fire, and even large trees are very fire-susceptible. Seedling establishment occurs from offsite seeds carried by birds.

Weather: Eastern redcedar foliage may be damaged by winter injury, and new seedlings are susceptible to frost-heaving. Eastern redcedar is tolerant of snow loads, but only moderately resistant to ice damage. It is extremely tolerant of drought and temperature extremes.

Air Pollution: Eastern redcedar is tolerant to sulphur dioxide and hydrogen fluoride. No symptoms of foliar injury have been noted on redcedars growing in areas of high ambient ozone.

Liquidambar styraciflua
Sweetgum
Hamamelidaceae *Map Section, Page 72*

Guild: opportunistic, long-lived intolerant
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows best on moist, alluvial soils but tolerates a wide range of site conditions; colonizes old fields and logged areas; often present in the understory of pine forests
Lifespan, yrs (typical/max): 200/300
Shade Tolerance: intolerant
Height, m: 15-45
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/30/150
Mast Frequency, yrs: 3
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Fires are unusual in the moist bottomlands where sweetgum grows. Sweetgum is not favored by fire. It has thin bark and is readily damaged or topkilled by fire. Sweetgum trees sprout prolifically from the root crown following fire, but repeated annual growing season burns will eventually deplete carbohydrate reserves and kill the plant. Dormant-season fires are less damaging than growing-season fires. Fire scars may be entry points for insects and diseases, but so long as the sapwood is not killed, basal wounds are often covered with a protective gum exudate. After repeated fires, sapwood may be killed and fungi and insects become established. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed burning in the growing season may be useful for controlling sweetgum where it is not a desirable species.

Weather: Sweetgum is very windfirm on upland sites.

Air Pollution: Sweetgum is intermediate to sensitive to ozone. Symptoms of foliar injury have been noted in areas of high ambient ozone. Seedlings exhibited reduced height growth and biomass accumulation under controlled fumigation with ozone.

Liriodendron tulipifera
Yellow-Poplar
Magnoliaceae *Map Section, Page 74*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: large deciduous tree
Ecological Role: found on many soil types but grows best on deep, well-drained loose textured soils; colonizes old fields and forest gaps; an early and persistent dominant in mixed-species forests
Lifespan, yrs (typical/max): 200/250
Shade Tolerance: intermediate
Height, m: 30-46
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 15/20/200
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early summer
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 8 yrs
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Yellow-poplar is an opportunistic species that is well adapted to occasional fire. Although yellow-poplar generally increases following low-intensity surface fires, it is not fire-dependent. Where yellow-poplars grow, fires are characteristically low- to moderate-intensity surface fires. Seedlings and saplings are thin-barked and very sensitive to fire. However, once the bark is > 1.3 cm (d.b.h. about 10 cm), individual trees are extremely fire resistant. Yellow-poplar trees are highly resistant to decay when wounded by fire. If topkilled, saplings and trees sprout from adventitious buds on the root crown or from root suckers. Seeds are resistant to heat damage. Seedling establishment is enhanced by fire; fire exposes yellow-poplar seed banks in the forest floor, and increases forest floor light levels. Prescribed burning can be used to promote or reduce yellow-poplar regeneration. Moderate intensity, growing-season fires have been used to kill yellow-poplar regeneration where it is competing with oak.

Weather: Yellow-poplar is susceptible to damage from sleet and glaze storms. Young trees are susceptible to late spring frost. Seedlings tolerate dormant-season flooding, but are intolerant of growing-season floods.

Air Pollution: Yellow-poplar is tolerant to sulphur dioxide but sensitive to ozone. It has exhibited symptoms of foliar injury in some areas of high ambient ozone, but not others. Foliar injury has been recorded, and seedlings exhibited variable height growth and biomass accumulation (some increase, some decrease) under controlled fumigation with ozone.

Maclura pomifera
Osage-Orange
Moraceae *Map Section, Page 76*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: small deciduous tree
Ecological Role: grows best on fertile, moist well-drained bottomlands, but also colonizes eroded areas, pastures, and disturbed openings; drought and heat tolerant
Lifespan, yrs (typical/max): No Data
Shade Tolerance: intolerant/ intermediate
Height, m: 5-12
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/25/65
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: No Data
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: aggregate of druplets/ to 50 m/ gravity, birds, livestock
Season of Germination: spring/summer
Seedling Rooting System: taproot
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Little direct information is known, but osage-orange populations probably tolerate occasional fire. It is probably topkilled by fire, and likely sprouts from adventitious buds in the root crown and from root suckers. Seedling establishment is promoted by exposed mineral soil, and may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and livestock.

Weather: Osage-orange is resistant to drought, hail, and ice glaze.

Air Pollution: No symptoms of foliar injury have been noted on osage-orange in areas of high ambient ozone.

Magnolia virginiana
Sweetbay
Magnoliaceae *Map Section, Page 78*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: small to medium-size evergreen tree or shrub
Ecological Role: found on moist, poorly drained soils in swamps and lowlands of the coastal plains; colonizes forest openings and clearcuts; moderately flood tolerant
Lifespan, yrs (typical/max): 80/ No Data
Shade Tolerance: intermediate
Height, m: 15-30
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): No Data
Mast Frequency, yrs: No Data
New Cohorts Source: seeds
Flowering Dates: late spring — summer
Flowers/Cones Damaged by Frost: no
Seedfall Begins: summer — early fall
Seed Banking: No Data
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupelike follicle/ to 100 m/ wind, birds
Season of Germination: spring
Seedling Rooting System: No Data
Sprouting: occasional, from stump or root-collar
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Sweetbay grows on moist sites, where fire rarely occurs. In the absence of fire, sweetbay becomes one of the dominant species in southern mixed hardwood forests. Although seedlings are susceptible to topkill and mortality from fire, larger trees are fire-resistant. Although the bark is relatively thin, a cork layer underneath the bark does not burn easily and consequently sweetbay is relatively fire resistant. Sweetbay sprouts after topkill from the root crown. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by water or birds.

Weather: Sweetbay is extremely tolerant of flooding in the dormant season.

Morus rubra
Red Mulberry
Moraceae *Map Section, Page 80*

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: grows on moist hillsides and along well-drained stream bottoms; occurs as scattered individuals in bottomland hardwood mixtures; produces abundant fruit for wildlife

Lifespan, yrs (typical/max): 100/125
Shade Tolerance: tolerant
Height, m: 5-21
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/30/85
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: summer
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: multiple druplets/ to 100 m/ birds, gravity
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Red mulberry is apparently excluded from certain forest communities by periodic fire, and is favored when fire is excluded. Red mulberry is sensitive to fire, because its bark is thin and roots are shallow. When topkilled, it sprouts from adventitious buds in the root collar or from root suckers. Red mulberry may colonize a burned site when the soil is moist from offsite seeds carried by birds and other animals.
Weather: Red mulberry is moderately tolerant of flooding, at least for a single growing season.

Nyssa aquatica
Water Tupelo
Cornaceae *Map Section, Page 82*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: large deciduous tree
Ecological Role: grows in saturated soils of flats and deep swamps; occurs in pure stands or mixed with baldcypress; does not tolerate suppression
Lifespan, yrs (typical/max): No Data
Shade Tolerance: intolerant
Height, m: 25-30
Canopy Tree: yes
Pollination Agent: insects, wind
Seeding, yrs (begins/optimal/declines): 30/No Data
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ variable/ water
Season of Germination: summer
Seedling Rooting System: shallow
Sprouting: prolific, from stumps
Establishment Seedbed Preferences
Substrate: muck or wet, poorly drained soil
Light: overstory shade
Moisture: wet
Temperature: neutral
Disturbance Response
Fire: Water tupelo grows in low, wet flats and swamps, where fire rarely occurs. A thin-barked tree, water tupelo is highly susceptible to fire. When water tupelo survives fire, fungi often invade wounded areas. Topkilled individuals probably sprout after fire. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried mainly by water.
Weather: Water tupelo is extremely tolerant of extended periods of flooding.

Nyssa sylvatica var. biflora
Swamp Tupelo
Cornaceae *Map Section Page 84*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: large deciduous tree
Ecological Role: found on swamp margins, low coves and year-round wet areas; occurs in mixtures with bottomland oaks, loblolly and slash pines
Lifespan, yrs (typical/max): 100+/No Data
Shade Tolerance: intolerant
Height, m: 24-40
Canopy Tree: yes
Pollination Agent: insects, wind
Seeding, yrs (begins/optimal/declines): 5/30/150
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: No Data
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ to 100 m/ gravity, birds
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts common
Establishment Seedbed Preferences
Substrate: variable, wet soils
Light: overstory shade
Moisture: wet
Temperature: neutral
Disturbance Response
Fire: Swamp tupelo grows in swamps where fire rarely occurs. If the peat soils of these swamps dry out, ground fires can occur, killing roots and resulting in high mortality. Topkilled individuals sprout from the root crown. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds or other animals.
Weather: Swamp tupelo is extremely tolerant of extended periods of flooding.

Nyssa sylvatica var. sylvatica
Black Tupelo (Blackgum)
Cornaceae *Map Section, Page 86*

Guild: opportunistic, dispersal limited (large-seeded)
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on a wide range of sites from stream bottoms to dry upper slopes; grows best on deep soils of lower slopes and coves; occupies intermediate crown positions in mixed-species forests; responds well to release
Lifespan, yrs (typical/max): 150/250
Shade Tolerance: tolerant
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: insects, wind
Seeding, yrs (begins/optimal/declines): 5/30/150
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ to 50 m/ gravity, birds
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Black tupelo is well adapted to periodic fire. Individual tupelo up to 10 cm d.b.h. are susceptible to topkill, but these trees sprout prolifically from the root crown and sometimes from root suckers. Larger trees have thick bark with high moisture content and are relatively resistant to fire. Fire-caused wounds can be entry points for heart-rot fungi. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Repeated prescribed fires, particularly in the early growing season when leaves are fully expanded, can be useful for controlling tupelo where it is not desired.

Air Pollution: Black tupelo is rated as tolerant to sulphur dioxide and ozone. Symptoms of foliar injury have been noted in some areas of high ambient ozone, but not in others.

Ostrya virginiana
Eastern Hophornbeam
Betulaceae *Map Section, Page 88*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: common on mesic and dry-mesic sites, but also occurs along well-drained stream bottoms; minor subcanopy component of mixed oak and northern hardwood forests
Lifespan, yrs (typical/max): 100/150
Shade Tolerance: very tolerant
Height, m: 9-16
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/30/100
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut in saclike bract/ to 100 m/ wind, birds
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Populations of eastern hophornbeam tolerate occasional, but not frequent fire. Eastern hophornbeam is susceptible to topkill from fire, but readily sprouts from adventitious buds in the root collar or from root suckers. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind or birds. The number of stems may increase following a single fire, but repeated prescribed fire is useful in controlling hophornbeam where is it undesirable.

Weather: Eastern hophornbeam is intolerant of flooding. It is relatively resistant to cold temperatures and to damage from wind, snow, and ice.

Air Pollution: Eastern hophornbeam is sensitive to sulfur dioxide and nitrous oxides, as well as chlorine and fluorine.

Oxydendrum arboreum
Sourwood
Ericaceae *Map Section, Page 90*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on dry open sites and ridgetops; also occurs on moist uplands and well-drained lowlands; grows as an understory or midstory associate in oak-hickory and oak-pine forests
Lifespan, yrs (typical/max): 100/120
Shade Tolerance: tolerant
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 20/30/100
Mast Frequency, yrs: 2

New Cohorts Source: seeds or sprouts
Flowering Dates: summer
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nonwinged/ to 50 m/ wind, gravity
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: prolific, from stumps
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Sourwood populations tolerate occasional, but not frequent fire. Following a single fire, sourwood usually increases in density. It is often topkilled by low-intensity fires, but sprouts prolifically and persistently from the root collar or from root suckers. Seedling establishment may occur from seeds of surviving trees onsite, but it seems likely that fire degrades site requirements for good seedling establishment (overstory shade and moist seedbeds). Repeated prescribed fires can eliminate sourwood from areas where it is undesirable.
Air Pollution: Symptoms of foliar injury have been noted in areas of high ambient ozone.

Pinus echinata
Shortleaf Pine
Pinaceae *Map Section, Page 92*

Guild: pioneer, dry-site intolerant
Functional Lifeform: large evergreen conifer
Ecological Role: successfully competes on dry ridges and nutrient-poor soils; on good sites forms a transitional type gradually replaced by more tolerant hardwood species
Lifespan, yrs (typical/max): 200/300
Shade Tolerance: intolerant
Height, m: 25-30+
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/40/280
Mast Frequency, yrs: 5-10
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common when young trees are badly damaged
Establishment Seedbed Preferences
Substrate: mineral soil
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Shortleaf pine is well adapted to occasional fire, but does not tolerate frequent fire. It decreases in density when fire is completely suppressed. Growing-season fires are more damaging than dormant-season fires. Shortleaf pine is most susceptible to fire in the first 6 to 10 years after establishment, but a well-developed basal stem crook protects dormant buds in seedlings. Trees up to 30 years of age can sprout from dormant buds in the root collar. Larger trees have thick bark and a high, open crown, and are resistant to stem and crown damage. Basal injuries are uncommon. Shortleaf pines can withstand considerable (up to 70%) crown scorch.
Fire-damaged trees are more susceptible to insect infestation. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Shortleaf pine regenerates well after fire, because exposed mineral soil and lack of competition promote seedling establishment. Prescribed fire has been used to prepare the necessary seedbed for shortleaf pine regeneration and to control competing hardwoods. More than one fire may be necessary where competing hardwoods sprout vigorously after fire.
Weather: Shortleaf pine is considered to be windfirm. It is susceptible to stem breakage from ice damage. Shortleaf pine mortality increases under extreme drought conditions.
Air Pollution: Shortleaf pine is intermediate in sensitivity to ozone. Seedlings exhibited reduced biomass accumulation under controlled fumigation with ozone.

Pinus elliottii
Slash Pine
Pinaceae *Map Section, Page 94*

Guild: opportunistic, long-lived intolerant
Functional Lifeform: large evergreen conifer
Ecological Role: best growth occurs on deep, well-aerated soils that supply moisture throughout the growing season; also successful on drier sites if young trees are protected from fire; gradually replaced by more tolerant hardwood species
Lifespan, yrs (typical/max): 150/200
Shade Tolerance: intolerant
Height, m: 24-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/20/150
Mast Frequency, yrs: 3
New Cohorts Source: seeds
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: fall if moisture is adequate
Seedling Rooting System: taproot
Sprouting: does not sprout
Establishment Seedbed Preferences
Substrate: mineral soil
Light: overstory shade
Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Slash pine thrives in a regime of frequent, low-intensity fire. Before fire suppression, fires occurred once or twice per decade, and were particularly frequent in the south Florida variety. Fires were ignited by lightning in late spring and summer. These fires reduced hardwood competition and exposed mineral soil, enhancing germination. Slash pine is highly tolerant of crown scorch and has thick, platy bark that dissipates heat. It is not susceptible to mortality from low- to moderate-intensity fires at a very early age (5-6 years), although short-term growth reduction may occur at high levels (>40%) of crown scorch. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed fire is an important tool in slash pine management. It is used periodically at short intervals throughout the life of a stand to reduce fuel hazards and competition from hardwoods, eliminate root rot fungus, and to expose mineral soil for seedbeds.

Weather: Slash pine is susceptible to ice damage and to windthrow on shallow soils.

Air Pollution: Slash pine is intermediate in sensitivity to ozone. Under controlled fumigation with ozone, slash pine seedlings exhibited reduced height growth and biomass accumulation, but variable change (some increase, some decrease) in photosynthesis rates.

Pinus palustris

Longleaf Pine

Pinaceae *Map Section, Page 96*

Guild: pioneer, dry-site intolerant
Functional Lifeform: large evergreen conifer
Ecological Role: found on a wide range of sites from poorly drained flats to dry ridgetops; most common on sandy, nutrient-poor, well-drained soils; colonizes large forest gaps and burned areas; in absence of fire is replaced by hardwoods and other pines
Lifespan, yrs (typical/max): 300/400
Shade Tolerance: intolerant
Height, m: 30-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/No Data
Mast Frequency, yrs: 5-7
New Cohorts Source: seeds
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early — late fall
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 50 m/ wind
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: only damaged grass-stage seedlings sprout
Establishment Seedbed Preferences

Substrate: mineral soil
Light: open areas only
Moisture: neutral
Temperature: neutral

Disturbance Response

Fire: Longleaf pine thrives in a low-intensity, high-frequency fire regime. Crown fires are rare. Spring and summer fires reduce competition and expose the mineral soil necessary for seed germination in the autumn. Before fire suppression, fire intervals were short (less than a decade), and fires were ignited by lightning in late spring and summer. Longleaf pine is resistant to fire-caused mortality in nearly all life stages. The exception is in the height-growth stage, where seedlings 0.3-0.9 m tall will die if the terminal bud is destroyed. Younger seedlings (“grass stage”) are tolerant of light fires. If top killed, seedlings sprout from the root collar. Once the terminal bud develops, it is protected by a moist, dense tuft of needles. In fact, these seedlings are stimulated into a growth stage by fire, which removes competition and reduces brown-spot needle blight infection. Larger trees are protected by thick, platy bark that dissipates heat. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Short-interval, low-intensity prescribed burning in longleaf pine stands is used to control brown-spot needle blight, stimulate height growth, reduce excess fuel, control understory hardwoods, improve wildlife habitat, thin stands, and prepare a mineral seedbed.

Weather: Longleaf pine is subject to lightning strikes and subsequent bark beetle infestation. It is subject to windthrow during high winds (hurricanes and tornados), and is moderately susceptible to ice damage. New germinants are susceptible to drought.

Pinus resinosa

Red Pine

Pinaceae *Map Section, Page 98*

Guild: pioneer, dry-site intolerant
Functional Lifeform: medium-size evergreen conifer
Ecological Role: common on well-drained sandy soils and gravelly ridges; successfully competes with short-lived associates jack pine, paper birch and aspen; on good sites is eventually replaced by more shade-tolerant conifers and hardwoods
Lifespan, yrs (typical/max): 200/300
Shade Tolerance: very intolerant
Height, m: 21-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/50/150
Mast Frequency, yrs: 3-7
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1-3 yrs
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: does not sprout
Establishment Seedbed Preferences

Substrate: mineral soil

Light: open with protective shade
Moisture: moist required
Temperature: neutral

Disturbance Response

Fire: Red pine thrives in a fire regime of alternating high-intensity, stand-replacing fires at long intervals (1-2 centuries) and moderate-intensity fires at moderate intervals (2-4 decades). Red pine decreases when fire is suppressed. Fire promotes good conditions for red pine regeneration, specifically a bare or lightly covered mineral seedbed free of brushy competition and an open canopy. Fire serves to reduce infestations by some insects. Seedlings are resistant to low- and moderate-intensity fires, if the terminal buds are not killed. Because red pine foliage is highly flammable, saplings and small trees are most vulnerable to fires. By about age 50, most red pines have developed thick bark and a high crown and are resistant to low- and moderate-intensity fires. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed fire is used for seedbed preparation. Summer fires, with variations in intensity (so some seed trees survive), are most effective in creating these conditions. However, not all canopy-opening fires result in red pine recruitment because good seed crops are infrequent.

Weather: Red pine is susceptible to mortality from flooding. It is subject to breakage and windfall from ice, sleet, and wind.

Air Pollution: Red pine is sensitive to sulphur dioxide but tolerant of ozone.

Pinus strobus
Eastern White Pine
Pinaceae *Map Section, Page 100*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: large evergreen conifer
Ecological Role: grows on well-drained, coarse-textured soils; colonizes old fields and establishes under open canopies of oak, hickory and birch; eventually replaced by more shade tolerant species
Lifespan, yrs (typical/max): 200/450
Shade Tolerance: intermediate
Height, m: 30-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/50/250
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind
Season of Germination: spring
Seedling Rooting System: shallow spreading
Sprouting: does not sprout
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral

Disturbance Response

Fire: Eastern white pine is opportunistic with respect to fire but not fire-dependent. Eastern white pine is broadly distributed and fire regimes depend on site and associated species. Formerly, this species grew in a regime of frequent (years to decades), light surface fires with occasional severe fires at long intervals (centuries). Eastern white pine regeneration is favored where some mature trees survive and fire creates a mineral seedbed and eliminates competitors. Eastern white pine is moderately fire resistant. Needles are low in resin and not very flammable. Trees taller than 18 m survive most light surface fires, because they have thick bark, branch-free boles, and are deeply rooted. Trees survive when <50% of the crown is scorched and roots are not badly damaged. Young trees (<50 years old) are relatively fire-sensitive. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed burning has been used successfully to promote eastern white pine regeneration in stands >80 years old.

Weather: Eastern white pine is susceptible to limb and stem breakage from ice and snow storms and to windthrow in dense stands.

Air Pollution: Eastern white pine is sensitive to ozone and sulphur dioxide. Symptoms of foliar injury have been noted in areas of high ambient ozone. Seedlings exhibited reduced height growth and photosynthesis under controlled fumigation with ozone. Variable response to ozone was noted among clones of eastern white pine.

Exotics: White pine blister rust (*Cronartium ribicola*) is an introduced stem rust of the 5-needle or white pine group, arriving in North America from Europe on diseased nursery stock around 1890. It causes stem and branch cankers that result in tree mortality, and has had profound ecological effects on white pine stands. *Ribes* (currant) plants are an alternate host, and in some situations, reducing *Ribes* density in white pine stands has been used successfully to manage damage to eastern white pine. Some trees are resistant to infestation.

Pinus taeda
Loblolly Pine
Pinaceae *Map Section, Page 102*

Guild: pioneer, dry/mesic intolerant
Functional Lifeform: large evergreen conifer
Ecological Role: grows on a wide range of sites from poorly drained flats to fertile well-drained coves and moist uplands; occurs in pure stands or mixed with wet-mesic hardwoods or dry-mesic oaks and pines; colonizes abandoned fields and burned areas; gradually replaced by more shade tolerant hardwoods
Lifespan, yrs (typical/max): 100/250
Shade Tolerance: intolerant/intermediate
Height, m: 25-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 12/25/No Data
Mast Frequency, yrs: 3-6
New Cohorts Source: seeds
Flowering Dates: early spring (variable)

Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: does not sprout
Establishment Seedbed Preferences
Substrate: mineral soil
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Loblolly pine is well adapted to fire, and frequent, low-intensity summer fires foster a pine-grassland community that degrades when fire is suppressed. Fire promotes the mineral soil seedbed necessary for loblolly regeneration and reduces competition from hardwoods. It reduces the incidence of damaging fungi in the soil. The needles of loblolly pine are low in resin and not highly flammable. Loblolly pine is big enough to resist low-intensity fire at 1.5 m tall. Mature trees survive low- to moderate-severity fires because of relatively thick bark and tall crowns. There is little mortality if less than 25 percent of the crown is scorched. Summer fires kill more trees than do winter fires. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind, and is abundant where mineral soil is exposed. Prescribed fire is used in loblolly pine stands for seedbed preparation, hardwood control, fuel reduction, and thinning.
Weather: Large, dominant loblolly pine trees are susceptible to windthrow during severe winds (hurricanes and tornados), especially on shallow soil and in recently thinned stands. Large trees are tolerant of flooding for one growing season. Loblolly pine seedlings are susceptible to extreme drought and freeze damage, and they are intolerant of flooding during the growing season.
Air Pollution: Loblolly pine is sensitive to ozone and hydrogen fluoride. Seedlings exhibited reduced height growth, biomass accumulation, and photosynthesis under controlled fumigation with ozone.

Pinus virginiana
Virginia Pine
Pinaceae *Map Section, Page 104*

Guild: pioneer, dry-site intolerant
Functional Lifeform: small to medium-size evergreen tree
Ecological Role: successfully competes on abandoned fields and dry ridges; on good sites a transitional type gradually replaced by more tolerant hardwood species
Lifespan, yrs (typical/max): 100/200
Shade Tolerance: intolerant
Height, m: 15-23
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 5/50/100
Mast Frequency, yrs: 3-4
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: 1-10 yrs
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: shallow spreading
Sprouting: common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response
Fire: Virginia pine is opportunistic with respect to fire but not fire-dependent. It requires some form of disturbance to regenerate; it decreases when fire or other disturbances are suppressed. It is thin-barked and has shallow roots, and so is sensitive to fire. Some large trees may survive a fire. In the past, moderate- to high-intensity fires probably burned at several-decade intervals, mostly during the dormant season. These fires served to expose mineral soil and eliminate competitors. Virginia pine does not sprout but aggressively colonizes burned sites with seed. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind.
Air Pollution: Virginia pine is sensitive to ozone. Symptoms of foliar injury have been noted in areas of high ambient ozone and under fumigation. Seedlings exhibited reduced height growth and biomass accumulation under controlled fumigation with ozone.

Platanus occidentalis
Sycamore
Platanaceae *Map Section Page 106*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: large deciduous tree
Ecological Role: common on river floodplains and sites with moist, alluvial soil; occasional pioneer on old fields and strip-mined land; replaces short-lived pioneers on river flats, but is a transitional type on drier soils
Lifespan, yrs (typical/max): 250/500
Shade Tolerance: intermediate
Height, m: 18-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/50/200
Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall, persistent seed balls disperse seed through the following spring
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: hairy achene/ >200 m/ wind, water
Season of Germination: spring

Seedling Rooting System: variable
Sprouting: common on young stems
Establishment Seedbed Preferences
  Substrate: variable
  Light: open areas only
  Moisture: moist required
  Temperature: neutral
Disturbance Response
  Fire: Sycamore increases with fire suppression. In bottomland hardwood communities, ground and surface fires occur frequently (5-8 years) when normal summer droughts extend into the autumn. Sycamore is unlikely to be a pioneer on burned sites, because on bottomlands, herbaceous vegetation grows rapidly and outcompetes seedlings. Uplands are probably too dry for successful sycamore establishment. Trees younger than 10 years old typically die after burning. Large trees survive most low-intensity fires but wounds may permit entry of disease. Topkilled trees sprout from adventitious buds in the root collar or from root suckers.
  Weather: Although sycamore grows on moist sites, it is intolerant of flooding during the growing season. Buds are susceptible to late spring frosts. A deep-rooted species, sycamore is relatively windfirm.
  Air Pollution: Sycamore is tolerant of sulphur dioxide but sensitive to ozone. Symptoms of foliar injury have been noted in areas of high ambient ozone (extremely sensitive). Seedlings exhibited reduced height growth and biomass accumulation under controlled fumigation with ozone. Variable response to fumigation was noted among related individuals.

Populus deltoides
Eastern Cottonwood
Salicaceae *Map Section, Page 108*

Guild: pioneer, moist-site intolerant
Functional Lifeform: large deciduous tree
Ecological Role: found on moist well-drained soils on open sites along streams and on bottomlands
Lifespan, yrs (typical/max): 60/200
Shade Tolerance: very intolerant
Height, m: 18-50
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 10/40/60
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: late spring — early summer
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: plumed/ >200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: shallow, spreading
Sprouting: common on small stems; occasional root sprouts
Establishment Seedbed Preferences
  Substrate: exposed mineral soil
  Light: open areas only
  Moisture: wet
  Temperature: neutral
Disturbance Response
  Fire: Eastern cottonwood seedling regeneration is favored following disturbances such as fire and flood. Fire thins the overstory, allowing more light penetration, and exposes the mineral soil so that seeds are able to establish if soil moisture is adequate. When topkilled, most eastern cottonwood trees sprout from adventitious buds in the root collar or from root suckers. Small trees (<20 years old) are highly susceptible to topkill, but older trees have very thick, protective bark. Wounded trees often contract heart rot. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind and water. Prescribed burning is not recommended in bottomland stands where trees are grown for timber and wood quality is important.
  Weather: Eastern cottonwood is tolerant of dormant-season flooding, but intolerant of growing-season flooding.
  Air Pollution: Eastern cottonwood is tolerant to intermediate in sensitivity to sulphur dioxide. Seedlings exhibited reduced height growth under controlled fumigation with ozone. Eastern cottonwoods showed variable response to ozone fumigation among clones.

Populus grandidentata
Bigtooth Aspen
Salicaceae *Map Section page 110*

Guild: pioneer, moist-site intolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on a wide range of sites but grows best on moist, fertile sandy uplands; vigorous root suckers develop on disturbed sites
Lifespan, yrs (typical/max): 60/100
Shade Tolerance: very intolerant
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/50/70
Mast Frequency, yrs: 4-5
New Cohorts Source: sprouts, seedlings (rare)
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late spring
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: plumed/ > 200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
  Substrate: mineral soil
  Light: open areas only
  Moisture: moist/wet required
  Temperature: neutral
Disturbance Response
  Fire: Bigtooth aspen populations increase after fire, and decrease when fire is suppressed. Although individual trees are susceptible to topkill, overstory removal and soil heating stimulate aspen root sprouting. Fire also creates a

suitable mineral seedbed and reduces competition. Stand-replacing fires are high-intensity surface fires, at intervals of several decades, most often occurring in the autumn when fuels are dry and leaf litter is deep. Low-intensity surface fires also occur. A thin-barked species, bigtooth aspen is very susceptible to fire injury and topkill, and even low-intensity fires kill seedlings and saplings. If large trees survive fire but are wounded, they often die of disease. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed fire is used as a management tool to regenerate bigtooth aspen stands. To maximize the number of suckers, moderate-intensity fires function to kill remaining canopy stems and remove duff following harvest. Low-intensity fires do not always induce sufficiently dense and vigorous suckers to regenerate a stand.

Weather: Bigtooth aspen is windfirm and resistant to ice and snow damage.

Air Pollution: Bigtooth aspen is sensitive to sulphur dioxide. No observed difference in the height of seedlings fumigated with ozone under controlled conditions has been noted. Variable response to fumigation among clones has been observed.

Populus tremuloides
Quaking Aspen
Salicaceae

Map Section, Page 112

Guild: pioneer, moist-site intolerant
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: an aggressive pioneer on a wide range of sites from moist uplands to dry ridges and slopes; pure stands are maintained by frequent disturbance (usually fire); often a transient type, replaced by longer-lived or more shade-tolerant species
Lifespan, yrs (typical/max): 70/125
Shade Tolerance: very intolerant
Height, m: 15-26
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 5/20/70
Mast Frequency, yrs: 4-5
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late spring
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: plumed/ >200 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: root suckers and stump sprouts common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: open areas only
Moisture: moist/wet required
Temperature: neutral
Disturbance Response

Fire: Quaking aspen is well adapted to fire. Even where quaking aspen was a minor component of the prefire vegetation, it often dominates a site after fire. Quaking aspen populations decrease when fire is suppressed. Overstory removal and soil heating stimulate quaking aspen root sprouting. Fire creates a suitable mineral seedbed and reduces competition. Low-intensity surface fires probably occurred at short intervals in the past (every decade or so) but moderate-intensity fires occurred at intervals of several decades. Thin-barked and easily topkilled, aspen sprouts prolifically from adventitious buds in the root crown or from root suckers. Aspens <15 cm d.b.h. are susceptible to topkill from low-intensity surface fires. Moderate-intensity fires topkill most trees. Larger trees may survive but are susceptible to decay organisms from basal wounds. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind. Prescribed fire is usually most successfully executed in spring or early summer (and sometimes in the autumn) when the surface litter is dead and cured and the weather is dry.

Weather: New leaves and shoots are susceptible to early spring frosts. It is subject to windthrow, especially when trees have asymmetric crowns. It is subject to defoliation from hail, and hail may bruise or kill young trees. Vigor is reduced by drought. Quaking aspen is resistant to ice storm damage.

Air Pollution: It is sensitive to ozone and sulphur dioxide and intermediate in sensitivity to hydrogen fluoride. Seedlings exhibited reduced biomass accumulation under controlled fumigation with ozone. A variable response to fumigation among clones was observed.

Prunus serotina
Black Cherry
Rosaceae

Map Section, Page 114

Guild: opportunistic, fast-growing understory tolerant
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows best on mesic sites and occurs in many mixed-species forest types; colonizes old fields and forest openings; shade tolerant seedlings must be released to survive
Lifespan, yrs (typical/max): 100/250
Shade Tolerance: intolerant/intermediate
Height, m: 20-38
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 10/25/100
Mast Frequency, yrs: 1-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: summer
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ to 100 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Black cherry populations tolerate occasional, low-intensity surface fires, but not frequent or moderate- to high-intensity fire. It is thin-barked and most trees are killed or topkilled by fire. Once larger than about 10 cm d.b.h., black cherry is moderately resistant to low-intensity fires. If topkilled, it resprouts prolifically from the root crown after one fire, but frequent fires would probably eliminate it. Germination is probably not promoted by fire. Black cherry does not require scarified seedbeds, and it seems likely that fire degrades site requirements for good seedling establishment. However, black cherry seedbanks are a source of copious quantities of seed, and the seed's stony endocarp and the soil covering probably provide some insulation from fire damage. Birds and other animals may also bring some seed into burned areas.

Weather: Black cherry is very intolerant of flooding and is susceptible to windthrow. Sapling and pole-sized trees are susceptible to bending and breaking after glaze or wet snow storms.

Air Pollution: Symptoms of foliar injury have been noted in areas of high ambient ozone and after fumigation (extremely sensitive). No difference in height and biomass accumulation was observed among seedlings fumigated with ozone under controlled conditions.

Quercus alba

White Oak

Fagaceae *Map Section, Page 116*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: large deciduous tree
Ecological Role: common upland oak found in mixed forests on dry ridge tops, upper slopes and rich coves; persists for long periods, but shade tolerance declines as trees grow large; responds well to release
Lifespan, yrs (typical/max): 300/600
Shade Tolerance: intermediate
Height, m: 24-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/75/200
Mast Frequency, yrs: 4-10
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common

Establishment Seedbed Preferences

Substrate: loose soil or humus, with litter cover
Light: overstory shade
Moisture: neutral
Temperature: 10° - 16°C favors germination

Disturbance Response

Fire: White oak is well adapted to periodic fire. It is unable to regenerate beneath the shade of parent trees and relies on periodic fires for its perpetuation. Fire exclusion has inhibited white oak regeneration through much of its range. Periodic fires in upland oak systems promote oak dominance by opening the canopy and reducing competition. Fires in upland forests tend to be low- to moderate-intensity and short in duration. Fires primarily occur during the dormant season at frequent intervals (once or more per decade to several decades). White oak is moderately resistant to fire, possessing thick, rough, scaly bark and deep roots. It becomes more fire resistant with age as bark thickens. When topkilled, seedlings and saplings readily and persistently sprout from the root crown or stump. Small fire scars are rapidly compartmentalized and damage is usually limited. Fire promotes seedling establishment by creating favorable seedbeds and reducing competition. However, acorns present during the fire are usually killed. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Low-intensity prescribed fire has been used successfully to promote white oak advanced regeneration.

Weather: White oak is moderately resistant to ice breakage, but sensitive to flooding.

Air Pollution: White oak is intermediate in sensitivity to sulphur dioxide and sensitive to ozone. Variable foliar injury has been observed under high ambient ozone conditions; no injury was noted under controlled fumigations.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus coccinea

Scarlet Oak

Fagaceae *Map Section, Page 118*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size deciduous tree
Ecological Role: grows on a variety of soils and is common on upper slopes and ridges; occurs with other xerophytic oaks and in pine-hardwood mixtures; moderately drought tolerant
Lifespan, yrs (typical/max): 150/250
Shade Tolerance: intolerant/intermediate
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/50/75
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts

Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable, with light litter cover
Light: light overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: In the absence of fire or other disturbance, the relatively short-lived scarlet oak is replaced by later successional species. Periodic fires in upland oak systems promote oak dominance by opening the canopy and reducing competition. Fires in upland forests tend to be low to moderate in intensity and short in duration. Fires primarily occur during the dormant season at frequent intervals (once or more per decade to several decades). Individually, scarlet oaks are susceptible to fire. Scarlet oak has thin bark, and even low-intensity surface fires can cause severe basal damage and high mortality. Decay can be extensive from even small wounds. Larger trees, with thicker bark, are more resistant than smaller trees. Topkilled scarlet oaks sprout vigorously from the adventitious buds in the root crown or from root suckers after fire. Fire may promote a good seedbed for acorn germination, but acorns present during the fire are usually killed. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed burning has been used to reduce oaks where they are not desired, most successfully where the stand is burned the summer after springtime harvest.

Weather: Moderately drought tolerant.

Air Pollution: Scarlet oak is intermediate to sensitive to ozone. No symptoms of foliar injury have been noted in areas of high ambient ozone.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus falcata var. falcata
Southern Red Oak
Fagaceae *Map Section, Page 120*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: common upland southern oak found in mixed-species forests on dry ridge tops and upper slopes; occasionally grows along streams in fertile bottomlands
Lifespan, yrs (typical/max): 150/200
Shade Tolerance: intermediate
Height, m: 20-25
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/50/75
Mast Frequency, yrs: 2-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: litter cover
Light: overstory shade
Moisture: moist
Temperature: neutral
Disturbance Response

Fire: In the absence of fire or other disturbance, the relatively short-lived southern red oak is replaced by later successional species. Periodic fires in upland oak systems promote oak dominance by opening the canopy and reducing competition. Fires in upland forests tend to be low- to moderate-intensity and short in duration. They have thin bark and are susceptible to topkill from fire, particularly small trees < 8 cm d.b.h. As trees grow larger, they become more resistant to fire. Growing-season fires cause more damage than dormant-season fires. Fire wounds on surviving trees allow entry of fungi which can cause heart-rot decay. Topkilled southern red oaks sprout vigorously from adventitious buds in the root crown or from root suckers after fire, and overall stem density may increase following fire. Species such as southern red oak that sprout after fire may become dominant in transition zones between pine and hardwood forests. Fire may promote a good seedbed for acorn germination, but acorns present during the fire are usually killed. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed fire may promote advance regeneration. Because oak seedlings are less susceptible to root kill by fire than competitors and because sprouts grow faster than seedlings, low-intensity fire can be used to promote advance oak regeneration. Repeat low-intensity fires seem to foster advance regeneration more effectively than single fires. Annual fires, however, will result in decreased stem density as root systems are killed.

Weather: Southern red oak decline and death has been associated with drought.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus falcata var. pagodifolia

Cherrybark Oak (Swamp Red Oak)

Fagaceae *Map Section, Page 122*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: large deciduous tree
Ecological Role: common on bottomlands and well-drained stream margins; occurs as scattered individuals in oak-hickory mixtures on alluvial floodplains and in pine-hardwood mixtures on moist uplands
Lifespan, yrs (typical/max): 150/275
Shade Tolerance: intolerant
Height, m: 30-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/50/75
Mast Frequency, yrs: 2-4
New Cohorts Source: seeds
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals, water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade or canopy gap
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Cherrybark oak grows on bottomland sites, where fire rarely occurs. A thin-barked species, it is susceptible to damage and topkilling from fire. Damaged trees are susceptible to infestation by insects. Cherrybark oaks sprout from adventitious buds in the root crown or from root suckers, more often in younger trees (seedlings and saplings) than older trees. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by water, birds, and other animals. It regenerates on areas protected from fire and grazing.

Weather: Cherrybark oak is susceptible to windthrow.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus laurifolia

Laurel Oak

Fagaceae *Map Section, Page 124*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size semi-evergreen tree
Ecological Role: common on floodplains, sandy river margins, and in moist woodlands; grows in mixtures with other wet-mesic hardwoods; establishes in the understory and rapidly moves into the canopy; heavy acorn crops are important for wildlife
Lifespan, yrs (typical/max): No Data
Shade Tolerance: tolerant
Height, m: 18-21
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/20/No Data
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no, exhibits mild dormancy
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals, water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common on small stems
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Laurel oaks benefit from fire suppression. Many laurel oak stands such as those on hydric hammocks owe their existence to protection from fire. Hardwood hammocks are extremely susceptible to fire damage, especially during the dry season. A dry-season surface fire may burn the organic soil down to the bedrock. If fire is suppressed, laurel oak expands from hydric hammocks into adjacent communities. A thin-barked species, laurel oaks are highly susceptible to damage and topkill from even low-intensity surface fires. Trees wounded by periodic fire commonly develop decay. Prescribed fire has been used in pine plantations to prevent hardwood establishment. Laurel oak up to about 8 cm d.b.h. can be controlled with prescribed dormant-season fires.

Weather: Intolerant of prolonged flooding.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus macrocarpa
Bur Oak
Fagaceae *Map Section, Page 126*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: large deciduous tree
Ecological Role: found on a wide range of sites from dry uplands and sandy plains to bottomlands and moist flats; very drought resistant
Lifespan, yrs (typical/max): 200/400
Shade Tolerance: intermediate
Height, m: 24-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 35/75/150
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable (without litter cover)
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Periodic fire favors bur oak communities. When fire is suppressed, seedlings of bur oak are unable to compete with other, more shade-tolerant species, and bur oak communities may be replaced by more shade-tolerant maple-basswood (*Acer* spp.-*Tilia* spp.) forests. Large bur oak trees have a thick, fire-resistant bark. Small grass fires are relatively common in some bur oak savannas, and typically topkill only young trees. Seedlings to large saplings sprout vigorously from the root crown or rhizomes when burned, but larger trees sprout less vigorously. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed fire has been used to prevent bur oak invasion to prairies. Annual burning for prairie maintenance can prevent bur oak from increasing. On other sites, an interval of up to 10 years between fires may be necessary to allow for the buildup of sufficient fuels for fire to reduce oak trees to shrubs and eliminate tree seedlings.

Weather: Bur oak is extremely resistant to drought and intolerant of flooding.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus marilandica
Blackjack Oak
Fagaceae *Map Section, Page 128*

Guild: pioneer, dry-site intolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: common on open areas and forest margins; colonizes dry, barren areas and survives on nutrient-poor sites
Lifespan, yrs (typical/max): 100/230
Shade Tolerance: intolerant
Height, m: 12-15
Canopy Tree: no
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): No Data
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: open areas only
Moisture: neutral
Temperature: neutral
Disturbance Response

Fire: Blackjack oaks grow in fire-prone environments (savannas and prairie margins), and are well adapted to periodic fire. However, very frequent fires diminish blackjack oak density and maintain prairies. When fire is suppressed in prairies, blackjack oak invades. Many present-day post oak-blackjack oak stands were former savannas. Blackjack oak is resistant to fire, but when topkilled it sprouts from the root crown or root suckers. Prolific sprouting after fire increases blackjack oak density. Only 3-4 years after fire, sprouts have been observed to produce acorns. Higher numbers of new germinants have been observed in recently burned areas, indicating that seedling establishment may be promoted by fire. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed fire is useful in controlling blackjack oak in prairie and savanna restoration where it is either used alone in 4-year intervals or in conjunction with herbicides.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus muehlenbergii

Chinkapin Oak

Fagaceae *Map Section, Page 130*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows on deep, well-drained soils along rivers, but is also found on dry, gravelly sites and limestone outcrops; occurs as scattered individuals in mesic and dry-mesic forests; often replaced by more shade-tolerant species on moist sites
Lifespan, yrs (typical/max): 150/250
Shade Tolerance: intermediate
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 30/50/150
Mast Frequency, yrs: irregular
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist
Temperature: neutral
Disturbance Response

Fire: Chinkapin oaks grow in fire-prone environments such as gallery forests in riparian corridors on prairie margins as well as in closed-canopy forests. The fires in gallery forests were short interval (years) and likely low in intensity. Where fire is suppressed, succession to more shade-tolerant maple-basswood (*Acer* spp.-*Tilia* spp.) forests occurs. Chinkapin oak seedlings and saplings are susceptible to damage and topkilling, but as they grow larger they develop thick, smooth bark that is fire-resistant; few large trees are killed by typical fires. Fire-caused wounds can be entry points for damaging fungi and insects. When topkilled, chinkapin oaks readily sprout from the root crown or from root suckers. Seedlings sprout persistently if topkilled several times. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Like many upland oaks, chinkapin would be likely to increase in a regime of low-intensity, short-interval fire.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus nigra

Water Oak

Fagaceae *Map Section, Page 132*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous or semievergreen tree
Ecological Role: grows on bottomlands and moist, well-drained uplands; moderately tolerant of seasonal flooding; colonizes old fields and invades pine forests; usually a transitional species on moist/wet hardwood sites
Lifespan, yrs (typical/max): 175/No Data
Shade Tolerance: intolerant
Height, m: 15-32
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/No Data
Mast Frequency, yrs: 2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist/wet required
Temperature: neutral
Disturbance Response

Fire: Apparent from its common name, water oak grows on bottomland sites and moist uplands where fire rarely occurs. Water oak litter and other fuel along riparian corridors are often moist and burn poorly. Short-interval low-intensity fires in both the dormant and growing season reduce the number of water oak saplings. Root systems are weakened and eventually killed by burning during the growing season. Water oak is extirpated from upslope forests by short-interval growing-season fires. A thin-barked species, it is susceptible to damage and topkilling from fire. Low-intensity surface fires topkill water oak less than about 8-10 cm d.b.h. The bark of larger trees is thick enough to protect the cambium from low-intensity fires and the buds are above the heat of the fire. Fire-caused wounds can be entry points for aggressive, damaging fungi. Water oaks sprout from adventitious buds in the root crown or from root suckers, more often in younger trees (seedlings and saplings) than older trees. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed burning has been used to control water oak where it is not desired, but fires are very difficult to ignite in the moist bottomlands where it typically grows. The most effective prescribed burning is done between late spring and early winter.

Weather: Water oak is susceptible to permanent standing water.

Air Pollution: Water oak is sensitive to sulphur dioxide.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus palustris

Pin Oak

Fagaceae *Map Section, Page 134*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on moist uplands and poorly drained alluvial floodplains; often replaces early bottomland pioneers
Lifespan, yrs (typical/max): 100/150
Shade Tolerance: intermediate/intolerant
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/40/125
Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
- **Substrate:** variable
- **Light:** overstory shade
- **Moisture:** moist required
- **Temperature:** neutral

Disturbance Response

Fire: A bottomland or moist upland species, fire is infrequent in pin oak communities during the growing season when the litter is damp; surface fires may occur in the dormant season, especially during drought years. A thin-barked species, it is susceptible to damage and topkill from even low-intensity surface fires. Seedlings and saplings are most susceptible; larger trees with thicker bark have more resistance. Fire-caused wounds are an entry point for decay organisms. Topkilled trees resprout from adventitious buds in the root collar or from root suckers. Fire is not a recommended management tool in the bottomland communities where pin oaks grow.

Weather: Pin oak is very tolerant of dormant-season flooding, but only moderately tolerant of growing-season flooding.

Air Pollution: Pin oak is tolerant of sulphur dioxide, but intermediate to sensitive to ozone. No symptoms of foliar injury noted in areas of high ambient ozone.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus phellos

Willow Oak

Fagaceae *Map Section, Page 136*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: large deciduous tree
Ecological Role: grows on bottomlands and moist, alluvial soils; moderately tolerant of seasonal flooding; grows in mixtures with other wet/mesic hardwoods; responds well to release; produces abundant acorn crops that benefit wildlife
Lifespan, yrs (typical/max): 200/No Data
Shade Tolerance: intolerant
Height, m: 24-37
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/No Data
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences

Substrate: variable, with litter cover
Light: overstory shade
Moisture: moist required
Temperature: neutral

Disturbance Response

Fire: Willow oak grows on bottomland sites where fire rarely occurs. Willow oak litter and other fuel along riparian corridors are often moist and burn poorly. A thin-barked species, it is susceptible to damage and topkilling from fire. Low-intensity surface fires topkill seedlings and saplings; larger trees with thicker bark have more resistance. It is more susceptible to growing-season fires than dormant-season fires. Fire-caused wounds can be entry points for insects and aggressive, damaging fungi. Willow oaks sprout from adventitious buds in the root crown or from root suckers, more often in younger trees (seedlings and saplings) than older trees. Short-interval low-intensity fires in both the dormant and growing season reduce the number of saplings. Root systems are weakened and eventually killed by burning during the growing season. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed burning has been used to control willow oak where it is not desired, but fires are very difficult to ignite in the moist bottomlands where it typically grows. The most effective prescribed burning is done between late spring and early winter.

Weather: Roots are inhibited by soil saturation during the growing season, and permanent standing water will kill willow oak.

Air Pollution: There was no observed change in height and biomass accumulation in seedlings fumigated with ozone under controlled conditions.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus prinus
Chestnut Oak
Fagaceae *Map Section, Page 138*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size deciduous tree
Ecological Role: common on dry, infertile soils on upland sites; grows in mixtures with upland oaks and dry-mesic hardwoods
Lifespan, yrs (typical/max): 300/400
Shade Tolerance: intermediate
Height, m: 20-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/75/200
Mast Frequency, yrs: 4-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common

Establishment Seedbed Preferences

Substrate: variable
Light: overstory shade
Moisture: neutral
Temperature: neutral

Disturbance Response

Fire: Chestnut oak is well adapted to periodic fire. It is moderately fire-resistant, surviving the low- moderate-intensity, short-duration surface fires typical of upland oak forests. Periodic fires promote upland oak dominance by opening the canopy and reducing competition. Fires primarily occur during the dormant season at intervals of years to decades. It has thick but furrowed bark and deep roots; resistance increases with tree size. It is susceptible to damage from fire in the bark furrows, but resistant to decay. When topkilled, seedlings and saplings readily and persistently sprout from adventitious buds on the root crown, root suckers, or from the stump. Fire favors chestnut oak acorn germination by removing the litter layer, but acorns present during the fire are usually killed. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Fire may increase the growth rate of chestnut oak. Where pine regeneration is desired, prescribed burning has been used to control oaks, most successfully where the stand is burned the summer following springtime harvest.

Air Pollution: Chestnut oak is tolerant of ozone and sulphur dioxide.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus rubra
Northern Red Oak
Fagaceae *Map Section, Page 140*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: large deciduous tree
Ecological Role: common upland oak found in mixed-species forests on deep, moist, well-drained soils; grows best on lower slopes and in deep ravines

Lifespan, yrs (typical/max): 200/400
Shade Tolerance: intermediate
Height, m: 20-30
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/50/200
Mast Frequency, yrs: 2-5
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: mineral soil with litter cover
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Northern red oak is well adapted to periodic fire. Without fire, northern red oak is outcompeted by more shade-tolerant species. Thinner-barked than species in the white oak group, it is somewhat susceptible to damage and topkill. Northern red oaks rapidly compartmentalize fire-caused wounds, but decay can be extensive. Larger trees with thicker bark are more resistant than smaller trees. Topkilled northern red oak seedlings, saplings, and pole-size trees sprout vigorously from the root crown or stumps. In the upland forests where northern red oaks grow, fires in the past were mostly low-intensity, dormant-season fires occurring at intervals of years to decades. Acorns present during the fire are usually killed, but large surviving trees are sources of seed, and offsite seeds may be carried by birds and other animals. Fire promotes a mineral seedbed and germination. Prescribed fire has been used successfully to increase advanced regeneration of northern red oak, but multiple fires are necessary to sufficiently reduce competition from other woody and herbaceous plants. Single, low-intensity fires can actually reduce the density of northern red oak.

Air Pollution: Northern red oak is tolerant of ozone and sulphur dioxide. A significant decrease in photosynthetic rates of seedlings fumigated with ozone was observed, but there was no observed change in biomass accumulation.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus stellata
Post Oak
Fagaceae *Map Section, Page 142*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size deciduous tree
Ecological Role: found in dry woodlands on rocky or sandy, nutrient-poor soils; grows in mixtures with other xerophytic oaks and pines; very drought tolerant
Lifespan, yrs (typical/max): 250/400
Shade Tolerance: intolerant
Height, m: 15-18
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 25/50/150
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: fall
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable, with litter cover
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Post oak is well adapted to periodic fire. If fire is infrequent or absent, post oak also is absent. Fuel type determines fire behavior and fire effects; in grassy fuels (prairie margins), fires are hotter and cause more mortality compared to fires fueled by hardwood litter. There is also more post oak mortality in trees growing near *Juniperus virginiana* trees, which burn intensely. In the absence of fire, trees spread and the grass dies back. If fire returns, post oaks are likely to survive because the reduction in grass fuel results in a much cooler fire. Fires in the past were mostly dormant-season fires occurring at intervals of years to decades. Post oak is a relatively thick-barked species, so most trees > 10 cm d.b.h. are moderately resistant to damage and topkill from fire. Fire-caused wounds may be entry points for damaging fungi, but post oaks are resistant to decay. When topkilled, seedlings and saplings sprout vigorously from adventitious buds in the root crown or from root suckers but trees over 25 cm d.b.h sprout poorly. Generally, because of sprouting, fires result in increased density of post oak trees. Repeated, annual fires will eventually weaken the rootstocks and kill trees. Post oak-blackjack oak forests may not revert to savannas with prescribed burning because these forests are fire-resistant and fires are much lower in intensity in closed canopy forests than in savannas. In this situation, frequent growing-season fires may be effective in reducing the density of trees because such fires are hotter than dormant-season fires, and belowground carbohydrate reserves are low.

Weather: Post oak is extremely resistant to drought, and very intolerant of flooding.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Quercus velutina
Black Oak
Fagaceae *Map Section, Page 144*

Guild: persistent, large-seeded, advance growth dependent
Functional Lifeform: medium-size to large deciduous tree
Ecological Role: grows on dry or very well-drained upland soils in mixtures with other upland oaks; also occurs on moist sites but is eventually replaced by more mesic associates
Lifespan, yrs (typical/max): 100/200
Shade Tolerance: intermediate
Height, m: 18-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/40/75
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds or sprouts
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nut (acorn)/ to 50 m/ gravity, birds, other animals
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: seedling and stump sprouts common
Establishment Seedbed Preferences
Substrate: mineral soil with light litter cover
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Black oak is well adapted to periodic fire. Black oak is characteristic as a community dominant only where major disturbances periodically open the canopy. Without fire, black oak will be dominated by more shade-tolerant species. Fuel type determines fire behavior and fire effects; in grassy fuels (prairie margins), fires are hotter and cause more mortality compared to fires fueled by hardwood litter. Fires in the past were mostly dormant-season fires occurring at intervals of years to decades. A relatively thick-barked species, it is moderately resistant to damage and topkill from fire. Larger trees (> 10 cm d.b.h.) are more resistant than smaller trees. Fire-caused wounds may be entry points for damaging fungi. Topkilled black oak sprout vigorously from adventitious buds in the root crown or from root suckers. Multi-stemmed clumps in which leaf litter accumulates are more susceptible to mortality than single stems. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds and other animals. Prescribed fire results in higher densities of black oak, but multiple fires in a short time period (for example, five fires in eight years) can weaken rootstocks and reduce black oak density. Where pine regeneration is desired, prescribed burning has been used to control oaks, and is most successful where the stand is burned the summer following springtime felling.

Air Pollution: Black oak is intermediate in sensitivity to ozone.

Exotics: Gypsy moth (*Lymantria dispar*) is a defoliator of eastern hardwood forests, introduced to Massachusetts from France in the late 1860's. It has spread throughout New England into Virginia and Michigan. Defoliation causes growth loss, decline, and mortality. It feeds on many tree species, but *Quercus* and *Populus* are the most susceptible taxa, and trees growing on xeric sites are the most vulnerable. Various efforts have been made to control it, with mixed results. A fungus, *Entomophaga maimaiga* introduced from Japan causes considerable mortality to gypsy moth populations. *E. maimaiga* levels are promoted by damp weather.

Robinia pseudoacacia
Black Locust
Leguminosae *Map Section, Page 146*

Guild: opportunistic, dispersal limited (sprout dependent)
Functional Lifeform: medium-size deciduous tree
Ecological Role: nitrogen-fixing; grows best on moist, loamy soils but establishes on a variety of disturbed sites; competes well on open uplands, old fields and in large forest openings; often planted for erosion control
Lifespan, yrs (typical/max): 60/100
Shade Tolerance: very intolerant
Height, m: 12-18
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 6/15/40
Mast Frequency, yrs: 1-2
New Cohorts Source: root suckers
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: no, impermeable seed coat requires scarification
Seed Type/Dispersal Distance/Agent: pod/ to 50 m/ gravity, wind
Season of Germination: spring
Seedling Rooting System: large, shallow roots
Sprouting: root suckers and stump sprouts common
Establishment Seedbed Preferences
Substrate: variable
Light: open areas only
Moisture: moist required

Temperature: neutral

Disturbance Response

Fire: Black locust is well adapted to periodic fire. Black locust vegetatively invades burned sites if it is present in the adjacent, unburned forest. Annual or very frequent fire probably removes black locust from the community by preventing sprouts from reaching fire-resistant size. Most fires are low intensity; the small leaflets of black locust in the litter layer tend to lie flat and stay damp (in contrast to leaves of *Quercus* and *Acer*, which dry out and crinkle up), effectively slowing surface fires. Small trees are susceptible to topkill but sprout rapidly from adventitious buds in the root crown or from root suckers. Following fire, black locust generally increases in density from both sprouts and new germinants. Both mowing and burning were found to be effective in reducing black locust cover; however, frequent burning may be necessary.

Weather: Black locust is moderately frost hardy.

Air Pollution: Black locust is tolerant to sulphur dioxide and nitrogen oxides, and intermediate in sensitivity to hydrogen fluoride. It is sensitive to ozone. Symptoms of foliar injury have been noted in some areas of high ambient ozone, but not in others (slightly sensitive). No foliar injury difference in height was observed in seedlings fumigated with ozone under controlled conditions.

Salix nigra

Black willow

Salicaceae *Map Section Page 148*

Guild: pioneer, moist-site, shade intolerant
Functional Lifeform: large deciduous tree
Ecological Role: common on floodplains and other wet soils; usually forms dense, pure stands; profuse rooting helps stabilize streambanks
Lifespan, yrs (typical/max): 70/85
Shade Tolerance: very intolerant
Height, m: 30-40
Canopy Tree: yes
Pollination Agent: insects, some wind
Seeding, yrs (begins/optimal/declines): 10/25/75
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes, but rare
Seedfall Begins: late spring — early summer
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: plumed/ > 200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: root collar sprouts common
Establishment Seedbed Preferences

Substrate: mineral soil
Light: open areas only
Moisture: moist/wet required
Temperature: neutral

Disturbance Response

Fire: Fires are rare in the bottomland areas where black willow typically occurs. Thin-barked and shallow-rooted, black willow is very susceptible to fire damage and typically decreases following fire (particularly seedlings and saplings). High-intensity fires can kill entire stands, and lower intensity fires often damage surviving trees. Damaged trees are highly susceptible to insects and decay organisms. Black willow sprouts from the root crown following fire. Fires that expose bare mineral soil may create a favorable seedbed for black willow establishment. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by wind and water. However, seed viability is greatly reduced by dry conditions, and establishment on burned sites depends on season of the burn, moisture availability, and amount of mineral soil exposed. Burning is useful in maintaining tallgrass prairies by inhibiting the invasion of black willow and other woody species.

Air Pollution: Black willow is sensitive to sulphur dioxide.

Salix spp.

Willow

Salicaceae *Map Section, Page 150*

Guild: Pioneer, moist-site, shade intolerant
Functional Lifeform: variable: shrublike or medium/large deciduous trees
Ecological Role: thrive in open, moist or wet areas; readily colonize scoured streambanks and wet flats; root systems spread rapidly and help control erosion
Lifespan, yrs (typical/max): No Data
Shade Tolerance: very intolerant
Height, m: 8-25
Canopy Tree: no
Pollination Agent: wind or insects
Seeding, yrs (begins/optimal/declines): 10/No Data
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: late spring — early summer
Seed Banking: seasonal, < 1 month
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: plumed/ > 200 m/ wind, water
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: root collar sprouts common
Establishment Seedbed Preferences

Substrate: mineral
Light: open areas only
Moisture: moist/wet required
Temperature: neutral

Disturbance Response

Fire: Fires are rare in the bottomland areas where most willows typically occur. Thin-barked and shallow-rooted, willows are susceptible to damage and topkill from fire, but sprout readily.

Air Pollution: Willows are sensitive to sulphur dioxide and tolerant of hydrogen fluoride.

Sassafras albidum

Sassafras

Lauraceae *Map Section, Page 152*

Guild: opportunistic, dispersal limited (sprout dependent)
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: scattered trees occur in many mesic and dry-mesic forest types; colonizes open, disturbed sites and may exist as small clones on old fields and along forest margins and fence rows; somewhat tolerant as a seedling, but rarely survives if overtopped
Lifespan, yrs (typical/max): 100/500
Shade Tolerance: intolerant
Height, m: 6-15
Canopy Tree: yes
Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 10/25/50
Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: summer
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: drupe/ variable/ gravity, birds
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: common, root sprouts form dense thickets
Establishment Seedbed Preferences
Substrate: moist loam with litter cover
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Sassafras increases in density on disturbed sites and is opportunistic with respect to fire. Moderate- to high-intensity fires promote higher densities of sassafras compared to low-intensity fires by creating an open forest structure that provides the open light conditions sassafras seeds require for germination. Such fires occur at intervals of at least 5 or more years. Annual burning may eliminate sassafras from the stand; decades of fire suppression also result in the elimination of sassafras. Sassafras is moderately resistant to damage and topkill from low-intensity fires and sprouts vigorously from the root crown or from root suckers, even after more than one fire. Although larger trees are more resistant to topkill, they are susceptible to injury and subsequent entry of decay organisms. Season of burning does not affect susceptibility to damage and topkill. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by birds. Frequent prescribed fire can improve spring and summer forage quality for wildlife in the southern *Pinus* forests, where sassafras often occurs.

Air Pollution: Symptoms of foliar injury have been noted on sassafras in some areas of high ambient ozone (extremely sensitive), but not in others.

Taxodium distichum var. distichum

Baldcypress

Taxodiaceae *Map Section, Page 154*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: large deciduous conifer
Ecological Role: grows on saturated or inundated sites and survives frequent or prolonged flooding; survives in mixed stands so long as it is not overtopped
Lifespan, yrs (typical/max): 250/400
Shade Tolerance: intermediate
Height, m: 20-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/No Data
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: small, non-winged, buoyant/ > 200 m/ gravity, water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common
Establishment Seedbed Preferences
Substrate: wet muck or sphagnum moss
Light: overstory shade
Moisture: wet required
Temperature: neutral
Disturbance Response

Fire: Although fires are rare in the swampy areas where baldcypress typically occurs, it is an important element in maintaining baldcypress dominance by reducing the number of species and relative importance of broadleaf species. The thin bark of cypress trees offers little protection against fire and, during years of drought when swamps are dry, fire kills most baldcypress trees. Under extreme drought conditions, ground fires in the peat may kill the roots of cypress trees, thus killing the plant. Intense ground fires also may kill seeds and roots in the soil, favoring replacement of baldcypress by willows (*Salix* spp.) and other hardwoods. When topkilled, baldcypress sprouts from the root crown and from root suckers. Trees > 60 years old are very resistant to decay when damaged. Seedling establishment may occur from seeds of surviving trees onsite or from offsite seeds carried by water.

Weather: Baldcypress is adapted to saturated and flooded soils, and is extremely windfirm.

Taxodium distichum var. nutans

Pondcypress

Taxodiaceae *Map Section, Page 156*

Guild: opportunistic, long-lived intermediate
Functional Lifeform: large deciduous conifer
Ecological Role: grows in shallow ponds and poorly drained flats
Lifespan, yrs (typical/max): 250/No Data
Shade Tolerance: intermediate
Height, m: 20-40
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/No Data
Mast Frequency, yrs: 3-5
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: small, non-winged/ to 100 m/ gravity, water
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common
Establishment Seedbed Preferences
Substrate: wet muck
Light: overstory shade
Moisture: wet
Temperature: neutral
Disturbance Response

Fire: Although fires are rare in the swampy areas where baldcypress typically occurs, it is an important element in maintaining baldcypress dominance by reducing the number of species and relative importance of broadleaf species. Pondcypress trees have thicker bark than *Taxodium distichum* var. *distichum* and are somewhat resistant to low-intensity fire. Other aspects of the response of pondcypress to fires are probably similar to *Taxodium distichum* var. *distichum*.

Weather: Pondcypress is adapted to saturated and flooded soils and is extremely windfirm.

Thuja occidentalis
Northern White-Cedar
Cupressaceae *Map Section, Page 158*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: medium-size evergreen tree
Ecological Role: grows in pure stands or conifer-hardwood mixtures in swamps or on low stream borders, moist pastures, or abandoned fields; withstands long periods of suppression and responds well to release
Lifespan, yrs (typical/max): 300/400
Shade Tolerance: tolerant
Height, m: 15-20
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 6/75/300
Mast Frequency, yrs: 2-5
New Cohorts Source: seeds or layerings
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 5 yrs +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring and summer
Seedling Rooting System: variable
Sprouting: layering common
Establishment Seedbed Preferences
Substrate: mineral soil, decayed wood, moss
Light: open with protective shade
Moisture: moist required
Temperature: warm
Disturbance Response

Fire Northern white-cedar stands are initiated by high-intensity crown fires that occur during dry, windy weather at intervals of centuries or more. Fire serves to remove competition and also removes the forest floor moss layer that dries out in the summer and prevents seedling establishment. The probability of fire on most northern white-cedar sites is low, but fires occasionally originate on drier sites and spread into northern white-cedar stands. Many northern white-cedar forests in the Lake States originated after fire. If the peat burns and the humus is destroyed, northern white-cedar may not become established for a long time. Thin-barked and with volatile foliage, it is highly susceptible to fire-caused mortality. Large trees may survive very low-intensity fires. Frequent fires may exclude northern white-cedar from some sites. It is highly resistant to decay. It reproduces well on moist organic soils exposed by fire if a seed source is nearby. Prescribed fire is recommended to aid in regeneration after harvest unless there is ample advance regeneration or if the organic soil is unsaturated. Fire removes the heavy slash that prevents regeneration and also prepares a favorable seedbed. Annual, low-intensity prescribed fires ignited in the autumn can be used to eliminate northern white-cedar that invades fens in the absence of fire.

Weather: Northern white-cedar is intolerant of flooding and susceptible to ice and snow damage. In exposed conditions, it is susceptible to drying during droughty winters. Older trees are susceptible to windthrow.

Air Pollution: Northern white-cedar is tolerant of ozone and sulphur dioxide. No symptoms of foliar injury have been noted in areas of high ambient ozone.

Tilia americana
American Basswood
Tiliaceae *Map Section, Page 160*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: large deciduous tree
Ecological Role: grows best on mesic sites but is also found on coarse soils and exposed ridges; occurs with sugar maple in the upper Midwest and is a minor component of hardwood mixtures in the Northeast
Lifespan, yrs (typical/max): 100/140
Shade Tolerance: tolerant
Height, m: 23-40
Canopy Tree: yes

Pollination Agent: insects
Seeding, yrs (begins/optimal/declines): 15/15/100
Mast Frequency, yrs: 1-2
New Cohorts Source: seeds or sprouts
Flowering Dates: early summer
Flowers/Cones Damaged by Frost: no
Seedfall Begins: early fall
Seed Banking: 1 yr +
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: nutlike drupe/ to 50 m/ gravity, birds
Season of Germination: spring
Seedling Rooting System: taproot
Sprouting: common, large and small stems sprout vigorously
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: American basswood is most common in forests with fire intervals of several decades to centuries. This species, along with some maple species, spreads where fire is suppressed, thus replacing species favored by periodic fire (for example, *Quercus*). American basswood is also encroaching onto former grasslands since fires have been suppressed. Once established, *Acer-Tilia* forests do not burn easily. Although it is thin-barked, basswood is somewhat resistant to low-intensity fire, and sprouts readily from the root crown or from root suckers when topkilled. Fire-damaged American basswood trees are susceptible to butt rot. Moderate-intensity fires actually favor American basswood density by creating light conditions that favor American basswood sprouts over *Acer saccharum* seedlings. American basswood sprouts are less abundant at long fire intervals, presumably because heavy shade in very dense stands is not tolerated by American basswood reproduction. Prescribed burning may be useful for encouraging good-quality sprouts in harvested American basswood stands, because post-fire sprouts occur lower on the stump and consequently develop less butt rot.

Weather: American basswood is extremely tolerant of late-spring frosts.

Air Pollution: American basswood is intermediate in sensitivity to sulphur dioxide, but tolerant of ozone and hydrogen fluoride.

Tsuga canadensis
Eastern Hemlock
Pinaceae *Map Section, Page 162*

Guild: persistent, slow-growing understory tolerant
Functional Lifeform: large evergreen conifer
Ecological Role: grows on cool, moist to very moist well-drained sites; survives for 100 yrs or more in the understory and suppressed trees grow well when released
Lifespan, yrs (typical/max): 450/800
Shade Tolerance: very tolerant
Height, m: 20-30+
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 20/30/450
Mast Frequency, yrs: 2-3
New Cohorts Source: seeds
Flowering Dates: late spring
Flowers/Cones Damaged by Frost: no
Seedfall Begins: late fall — winter
Seed Banking: up to 1 yr
Cold Stratification Required: yes
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ wind
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: does not sprout
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: warm
Disturbance Response

Fire: Eastern hemlock grows in moist environments and in association with hardwoods that rarely burn. It tends to increase in density with fire suppression. In a strong wind, fires that start in a cutover area, a windfall area, or an area with dead standing timber may carry into stands where hemlocks grow. Seedlings and saplings are killed by even low-intensity fires, but larger trees have some resistance, due to thicker bark. However, eastern hemlocks have shallow roots that are susceptible to fire damage. After several decades, eastern hemlock may invade burned sites. Germination and seedling establishment may be promoted by low-intensity prescribed fires that expose partially decomposed litter but do not kill or topkill overstory trees that shade the seedbed to prevent drying.

Weather: Eastern hemlocks are extremely susceptible to drought, especially in the seedling stage. They are also susceptible to winter drying on warm, windy days. Heavily thinned stands are susceptible to windthrow.

Air Pollution: Eastern hemlock is sensitive to sulphur dioxide, and intermediate to sensitive to ozone. Symptoms of foliar injury have been noted in some areas of high ambient ozone, but not in others; no foliar injury symptoms have been observed after controlled fumigation with ozone. No difference was observed in height growth of seedlings fumigated with ozone under controlled conditions.

Ulmus alata
Winged Elm
Ulmaceae *Map Section, Page 164*

Guild: pioneer, spring-dispersed, moist-site tolerant
Functional Lifeform: small to medium-size deciduous tree
Ecological Role: grows on a wide range of sites from moist flats to dry uplands; colonizes old fields and forest openings; usually occurs as scattered individuals in upland oak forests and bottomland hardwood mixtures
Lifespan, yrs (typical/max): 125/No Data

Shade Tolerance: tolerant
Height, m: 12-24
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): No Data
Mast Frequency, yrs: No Data
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: No Data
Seedfall Begins: late spring
Seed Banking: seasonal, < 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ up to 100 m/ wind, water, birds
Season of Germination: spring
Seedling Rooting System: No Data
Sprouting: No Data
Establishment Seedbed Preferences
Substrate: variable
Light: open areas only
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: There is no specific information available about the fire response of this species. Its association with upland *Quercus* species and bottomland hardwoods suggests that is grows on sites more fire-susceptible than the moister sites typical of *Ulmus americana* and *U. rubra*. It is likely to sprout from the root crown in response to topkill during low-intensity fires.

Exotics: The dominance of all North American elm species has been significantly decreased by Dutch elm disease, caused by an exotic wilt fungus (*Ceratocystis ulmi*) that was introduced from Europe in 1930. It is spread by two species of elm bark beetles, one European (*Scolytus multistriatus*) and the other native (*Hylurgopinus rufipes*). Juvenile trees have some resistance to the disease, and elms produce wind-borne seeds before they die. Elms will likely persist in the forest as an understory species.

Ulmus americana
American Elm
Ulmaceae *Map Section, Page 166*

Guild: pioneer, spring-dispersed, moist-site tolerant
Functional Lifeform: large deciduous tree
Ecological Role: grows best on rich, well-drained soils on stream terraces and moist uplands; colonizes wet areas on open, disturbed sites; also common under pioneer species; rarely becomes dominant because of its susceptibility to the wilt fungus *Ceratocystis ulmi* (Dutch elm disease)
Lifespan, yrs (typical/max): 175/300
Shade Tolerance: intermediate
Height, m: 30-38
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/40/125
Mast Frequency, yrs: 1
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late spring
Seed Banking: up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 200 m/ wind, birds, water
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: mineral soil
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Fire rarely occurs in the moist areas where American elm typically grows. When fire does occur and conditions are dry, American elm greatly decreases following fire. Alternatively, American elm invades where fire is suppressed. Fire occurs at long intervals in the northern parts of its range, but more often in southern bottomlands, where autumn and early spring fires cause much damage. Low- and moderate-intensity fires topkill seedlings and saplings, and often damage larger trees. Wounded trees are susceptible to heart-rot fungi. Small topkilled trees sprout from the root crown or from root suckers. Wind- and water-dispersed seed are important in the establishment of American elm following fire.

Weather: American elm tolerates dormant-season flooding but not growing-season flooding. Small trees are susceptible to sunscald. Open-grown trees are susceptible to ice and snow damage. It is windfirm and moderately drought resistant.

Air Pollution: American elm is intermediate to sensitive to sulphur dioxide, and is sensitive to ozone. It is tolerant of hydrogen fluoride. No symptoms of foliar injury were noted in areas of high ambient ozone.

Exotics: The dominance of all North American elm species has been significantly decreased by Dutch elm disease (*Ceratocystis ulmi*), an exotic wilt fungus that was introduced from Europe in 1930. It is spread by two species of elm bark beetles, one European (*Scolytus multistriatus*) and the other native (*Hylurgopinus rufipes*). American elms are the most susceptible of all the elms. Juvenile trees have some resistance to the disease, and elms produce wind-borne seeds before they die. Elms will likely persist in the forest as an understory species.

Ulmus rubra
Slippery Elm
Ulmaceae *Map Section, Page 168*

Guild: pioneer, spring-dispersed, moist-site tolerant
Functional Lifeform: medium-size deciduous tree
Ecological Role: found on a wide range of sites from river terraces to dry hillsides; usually a subcanopy component of wet-mesic forests but also occurs as an occasional tree in

oak-hickory mixtures
Lifespan, yrs (typical/max): 200/300
Shade Tolerance: tolerant
Height, m: 18-22
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/40/150
Mast Frequency, yrs: 2-4
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late spring
Seed Banking: seasonal, up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 100 m/ gravity, wind
Season of Germination: spring
Seedling Rooting System: shallow
Sprouting: stump sprouts, rhizome sprouts, layerings common
Establishment Seedbed Preferences
Substrate: variable
Light: overstory shade
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Fire rarely occurs in the moist areas where slippery elm typically grows. When fire does occur and conditions are dry, slippery elm greatly decreases following fire. Small topkilled trees sprout from the root crown or from root suckers. Wind- and water-dispersed seed are important in the establishment of slippery elm following fire. Little other specific information is known about this species, but response to wounding is probably similar to *U. americana*.

Weather: Slippery elm is somewhat tolerant of flooding. It is susceptible to ice damage.

Exotics: The dominance of all North American elm species has been significantly decreased by Dutch elm disease, caused by an exotic wilt fungus (*Ceratocystis ulmi*) that was introduced from Europe in 1930. It is spread by two species of elm bark beetles, one European (*Scolytus multistriatus*) and the other native (*Hylurgopinus rufipes*). Juvenile trees have some resistance to the disease, and elms produce wind-borne seeds before they die. Elms will likely persist in the forest as an understory species.

Ulmus spp.
Elm
Ulmaceae

Map Section, Page 170

Guild: pioneer, spring-dispersed, moist-site, shade tolerant
Functional Lifeform: variable: small to large deciduous trees
Ecological Role: common subcanopy components of many wet-mesic forest types; also may occur on upland sites, but usually as occasional trees
Lifespan, yrs (typical/max): varies with species; 125-200/ 300
Shade Tolerance: intermediate to tolerant
Height, m: 12-38, depending on species
Canopy Tree: yes
Pollination Agent: wind
Seeding, yrs (begins/optimal/declines): 15/40/125
Mast Frequency, yrs: 1-4, varies with species
New Cohorts Source: seeds or sprouts
Flowering Dates: early spring
Flowers/Cones Damaged by Frost: yes
Seedfall Begins: late spring
Seed Banking: seasonal, up to 1 yr
Cold Stratification Required: no
Seed Type/Dispersal Distance/Agent: winged/ to 200m/ wind, water, birds
Season of Germination: spring
Seedling Rooting System: variable
Sprouting: stump sprouts and root suckers common
Establishment Seedbed Preferences
Substrate: mineral soil or variable
Light: variable, open or shaded
Moisture: moist required
Temperature: neutral
Disturbance Response

Fire: Fire rarely occurs in the moist areas where elms typically grow. When fire does occur and conditions are dry, elm greatly decreases following fire. Small topkilled trees sprout from the root crown or from root suckers. Wind- and water-dispersed seed are important in the establishment of elm following fire.

Exotics: The dominance of all North American elm species has been significantly decreased by Dutch elm disease, an exotic wilt fungus (*Ceratocystis ulmi*) that was introduced from Europe in 1930. It is spread by two species of elm bark beetles, one European (*Scolytus multistriatus*) and the other native (*Hylurgopinus rufipes*). American elms are the most susceptible of all the elms. Juvenile trees have some resistance to the disease, and elms produce wind-borne seeds before they die. Elms will likely persist in the forest as an understory species.

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Part 3--*Summary Statistics for the 80 Species*

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In this section, we provide statistical summaries of the frequency that the species fall into classes of selected variables so that individual species can be evaluated in the context of the entire suite of common species. Overall characteristics for the 80 species as a whole also can be visualized. Figures 3-4 and 22-34 are summaries of variables reported in Part 2 -- Life History, and as such, are derived from the literature. Figures 5-21 and 35-40 summarize variables from Part 1 -- Atlas, and are derived from FIA, environmental variables, or modeled potential outcomes in the geographic information system. Most are represented by pie charts given on subsequent pages. It should be noted that those species with a more restricted range will appear more frequently below as the extremes; those species with a wider range will be characterized with values closer to the overall mean.

Taxonomic Family

Twenty-two families are represented by the 80 species (Fig. 3). The Fagaceae (beech family) has the most species, with 16. All but one of these are oaks. There are also 9 from the Pinaceae (pine family), 6 from the Juglanaceae (walnut family) and Ulmaceae (elm family), and 5 each from the Salicaceae (willow family), Betulaceae (birch family), and Aceraceae (maple family). At the other end of the spectrum, seven families are represented by only one species.

Guild

The 80 species are divided into 14 guilds that are differentiated on the basis of persistence, shade tolerance, longevity, dispersal, and site quality (Fig. 4). The primary guild, with 19 species, is occupied by species that are persistent, large seeded, and depend on advance growth for successful regeneration. Oaks (*Quercus* spp.) and hickories (*Carya* spp.) exclusively form this guild. Next in importance is a guild whose species are persistent, slow-growing, and tolerant to shade in the understory. These 11 species consist of a mix of species including *Acer saccharum, Ostrya virginiana, Abies balsamea, Tilia americana, and Fagus grandifolia.* Another 9 species are also shade tolerant, but more opportunistic and fast-growing, including several ashes (*Fraxinus* spp.), *Cornus florida*, and *Celtis* spp. Next is a group of 7 species that are opportunistic, long-lived, and shade intermediate, represented by *Betula* spp., *Liriodendron tulipifera*, and *Taxodium* spp.

Area in Range

The area in range is simply the total area occupied by the species, according to the FIA data. This value ranges from 0.25 million km^2 for *Taxodium distichum* var. *nutans* to 2.69 million km^2 for *Prunus serotina* (Fig. 5). A main criterion for inclusion of species in this atlas is that at least 100 counties had to have the species present; so, many more rare species occupy even smaller ranges but are not included in this

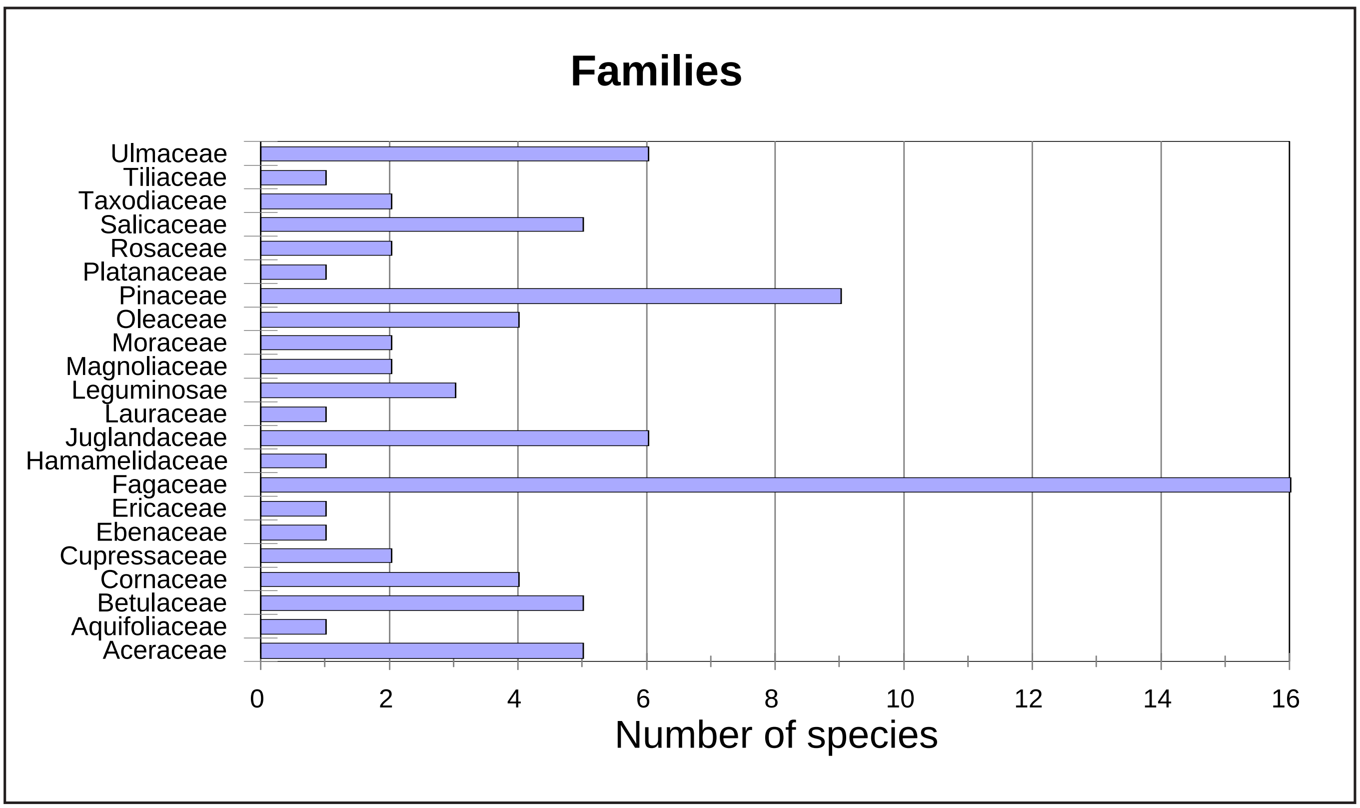

Figure 3.–Number of species (out of 80) for each of 22 families.

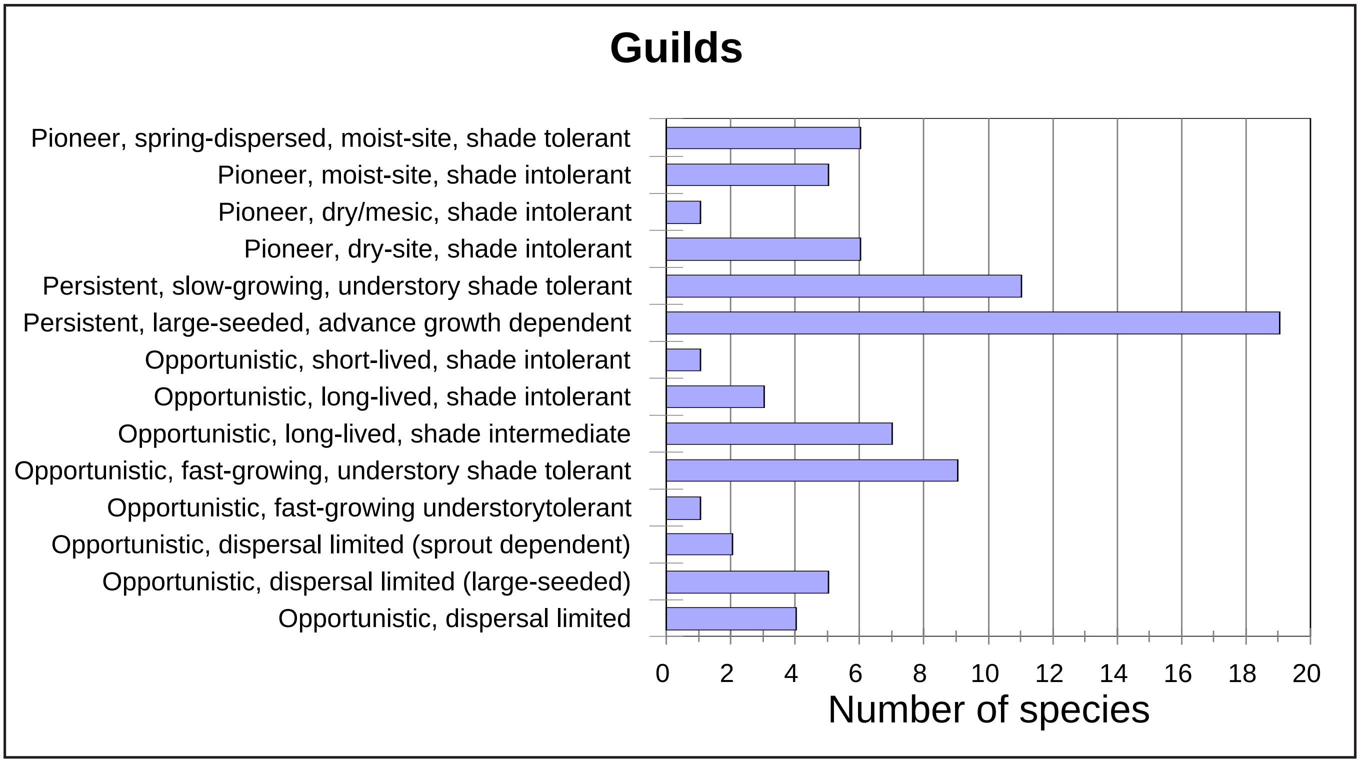

Figure 4.–Number of species for each of 14 guilds.

analysis. Other species with small ranges (< 0.5 million km^2) include: *Thuja occidentalis*, *Betula lenta, Nyssa aquatica, Quercus palustris,* and *Abies balsamea*, wheras other species with large ranges (> 2.0 million km^2) include *Acer rubrum, Quercus alba, Ulmus americana*, *Q. rubra*, *Ostrya virginiana*, and *Fraxinus pennsylvanica*.

If one considers area in range according to Little (1991, 1977), some differences exist in estimates of area. Little estimates range with a polygon around known locations, whereas FIA only includes the area if the county had the species recorded from a plot within its borders. With FIA sampling, only a very small fraction of the total forest land is sampled, and there is a high probability of less common tree species being missed with FIA. As such, the average range size for the 80 species increases from 1.09 million km^2 using FIA data to 1.58 million km^2 using Little's range estimates. Further, Little (1971) has a much larger share of species with ranges exceeding 1.5 million km^2 (Fig. 6). According to Little, the smallest range is 0.12 million km^2 for *Maclura pomifera* with the largest range being 3.78 million km^2 in *Ulmus americana*.

Average Importance Value

Average importance value (IV) indicates the relative importance or abundance of the species when it is found on an FIA plot. Some species may be relatively small in range, but quite prominent when it is found. If the species were found in a monoculture at each FIA plot throughout its range, the IV would be 200. Here, the highest average IV was found in *Pinus taeda*,

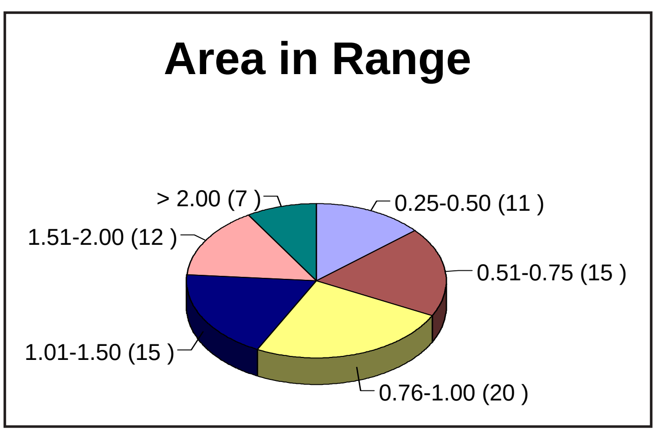

Figure 5.–Number of species (in parentheses) by area of species ranges according to FIA data, million km^2.

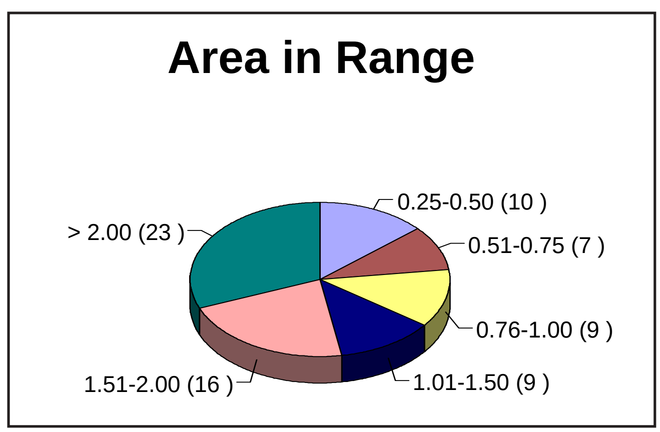

Figure 6.–Number of species (in parentheses) by area of species ranges according to Little's (1971, 1977) data, million km^2.

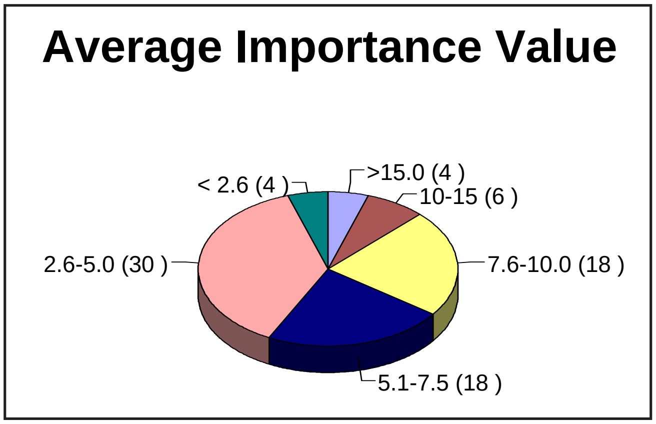

Figure 7.–Number of species (in parentheses) by average importance value (0-200 scale) for 80 species.

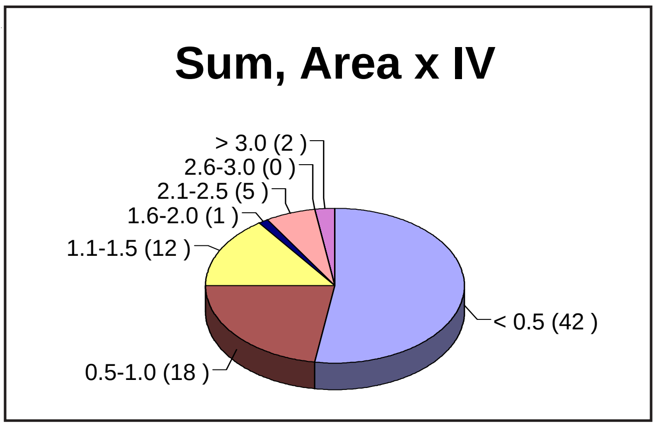

Figure 8.–Number of species (in parentheses) by sum of the product of species area (FIA) and importance value (IV), x 10^8.

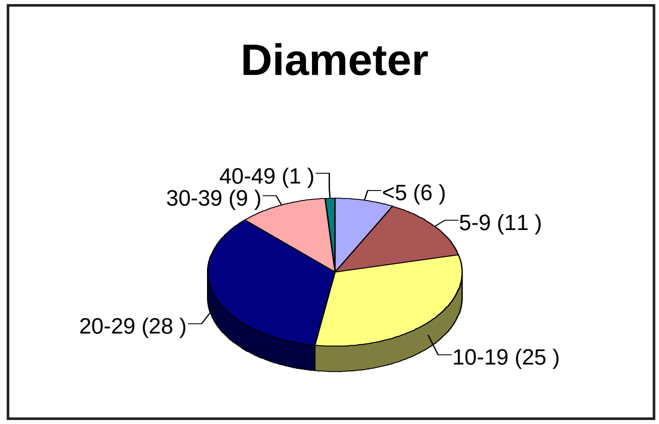

Figure 9.–Number of species (in parentheses) by average diameter, cm.

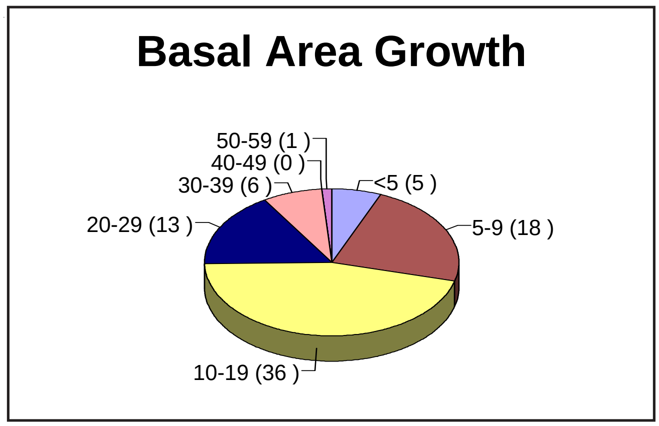

Figure 10.–Number of species (in parentheses) by basal area growth, cm^2/yr.

with 30.8 average IV. This species, loblolly pine, is often found in pure stands in the southeast. *Pinus elliottii*, slash pine, is also found in relatively high abundance, followed by *Liquidambar styraciflua*, *Populus tremuloides, Acer rubrum, Acer saccharum, Quercus macrocarpa, Abies balsamea, Populus deltoides,* and *Ulmus americana*, which all average above 10 for IV (Fig. 7). At the other end, species such as *Diospyros virginiana*, *Platanus occidentalis*, *Quercus falcata* var. *pagodaefolia*, and *Cercis canadensis* are exclusively recorded as a minor species (< 2.5 IV). Most species have an IV between 2.6 and 10.0.

Σ Area X Importance Value

With this variable, we evaluate the overall prominence of the species. We factor in total area of the species' range as well as its average IV. Those species that occupy large areas and are common everywhere get the highest scores. *Acer rubrum*, which ranks second in total area and fifth in average IV, has the highest score for this variable (3.66×10^8). It is a common species capable of vigorous growth in a wide variety of habitats (Golet et al. 1993). *Pinus taeda* also scores high. Other species scoring more than 2.0×10^8 include *Ulmus americana*, *Acer saccharum*, *Quercus alba, Fraxinus pennsylvanica*, and *Liquidambar styraciflua*. On the other hand, more than half of the species have values $< 0.5 \times 10^8$ (Fig. 8).

Diameter

We measure the diameter of the tree at breast height (in cm). For all species, the average diameter at the time of measurement was 19 cm, with a range of 0.3 to 49.9 cm (Fig. 9). Largest species include, in decreasing order: *Populus deltoides, Taxodium distichum, Platanus occidentalis, Quercus palustris,* and *Acer saccharinum*. The smallest trees include *Acer pensylvanica, Crataegus* spp*., Cercis canadensis, Diospyros virginiana, Cornus florida,* and *Carpinus caroliniana*. The majority of tree species (53) lie in the range of 10 to 29 cm (Fig. 9).

Basal Area Growth

This variable is a measure of annual growth, in cm^2 per year (per plot). It is derived from the estimates of diameter at the current and previous FIA measurement, and is only available for plots that have two or more measurements. Nearly half of all species have annual growth in the range of 10-19 cm^2/yr (Fig. 10), and the mean is 16 cm^2/yr. The range is wide, however, with *Crataegus* spp. having only 1.3 cm^2/yr of growth and *Populus deltoides* 54.1 cm^2/yr. Other slow-growing species include *Cornus florida, Ostrya virginiana, Carpinus caroliniana,* and *Ilex opaca*, and other fast-growing species include *Acer saccharinum* and *Quercus falcata* var. *pagodifolia*.

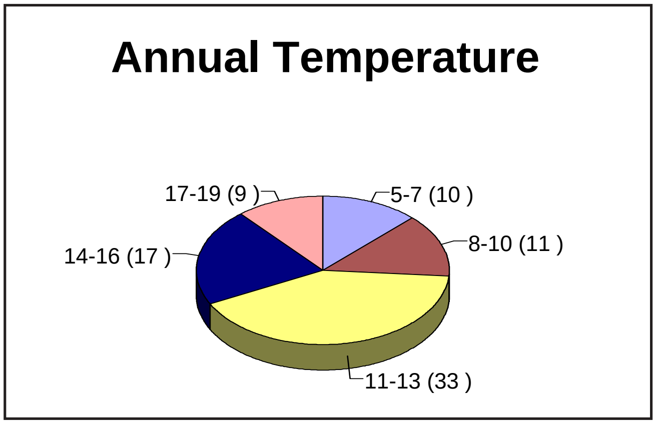

Figure 11.–Number of species (in parentheses) by annual temperature, °C.

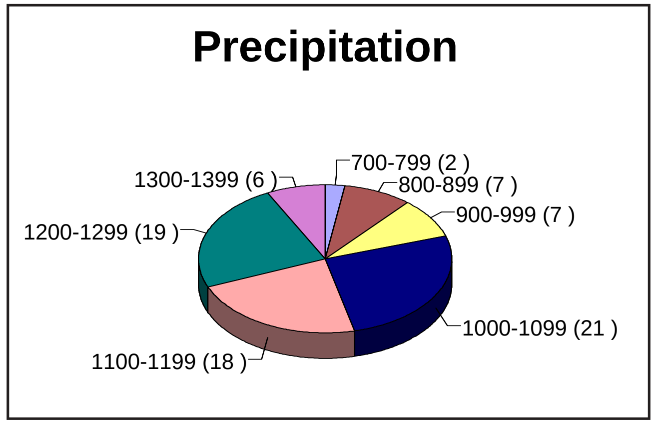

Figure 13.–Number of species (in parentheses) by precipitation, mm/yr.

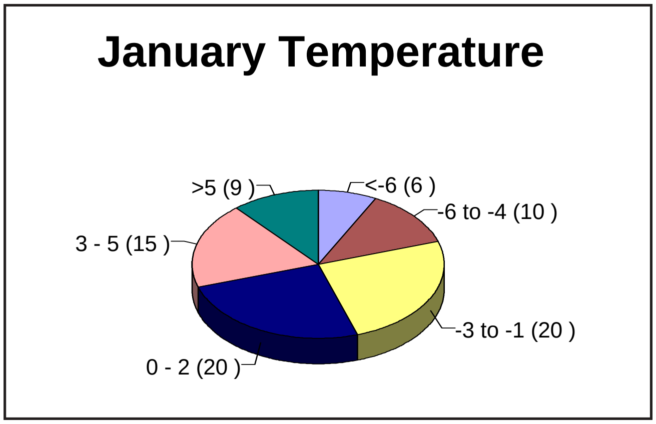

Figure 12.–Number of species (in parentheses) by January temperature, °C.

Annual Temperature

Annual temperature represents the median annual temperature (°C) of the species over its entire range. Ten northern species have median temperatures < 8 °C, and nine southern species have temperatures that exceed 17 °C (Fig. 11). The remaining 61 species fall between the extremes, with 33 species having a median annual temperature of 11 to 13 °C.

January Temperature

January temperature can often be a limiting factor for the survival of tree species, and there is a large range in median January temperatures among the 80 species (-9.7 °C for *Abies balsamea* to +9.6 °C for *Taxodium distichum* var. *nutans*) (Fig. 12). Other species with cold (< -6 °C) median temperatures include *Thuja occidentalis, Betula papyrifera, Fraxinus nigra, Pinus resinosa*, and *Populus tremuloides*. Those utilizing relatively warm (> 8 °C) January temperatures include *Quercus laurifolia, Magnolia virginiana, Pinus elliotti*, and *P. palustris*. Half of the species have median January temperatures between -4 and +3 °C, with the mean temperature for all 80 species being right at 0 °C.

Precipitation

The range for median precipitation among the 80 species is 790 to 1,320 mm, with the overall median at 1,125 mm (Fig. 13). Half of the species have median precipitation values between 1,000 and 1,200 mm. Species at the low end include *Betula papyrifera, Thuja occidentalis*, and *Quercus macrocarpa*, and species at the high end include *Nyssa aquatica, Pinus palustris,* and *Celtis laevigata*.

Potential Evapotranspiration

The potential evapotranspiration (PET) is an indicator of the amount of water a stand of trees could pump to the atmosphere if there was unlimited soil water, and is related mainly to heat and radiation, but modified by humidity and wind speed (Stephenson 1990). The range for PET, reported on an average monthly basis, is 41 mm/month for *Abies balsamea* to 79.6 mm/month for *Taxodium distichum* var. *nutans* (Fig. 14). These are the same species identified as the extremes for median January temperature, again reflecting the relationship between PET and heat.

pH

The mean soil pH for all 80 tree species was 4.76, with a range of 3.9 (*Pinus virginiana*) to 6.1 (*Quercus macrocarpa*) (Fig. 15). The acid nature of the soils has considerable consequences with respect to nutrient availabilities and decomposition. Soils tend to be most acid in the Appalachians, where *Pinus virginiana* is highly concentrated, and higher in pH in the western part of the study area where prairie soils dominate, exemplified by *Quercus macrocarpa* and *Populus deltoides*.

Permeability

Permeability is the rate of water infiltration through the soil column; clayey soils typically will have a slow permeability, whereas sandy soils will have much higher values. The range among the 80 species is 1.0 cm/hr for *Maclura pomifera* to 5.9 cm/hr for *Taxodium distichum* var. *nutans* (Fig. 16). Most species (57) have permeability values < 2.0 cm/hr.

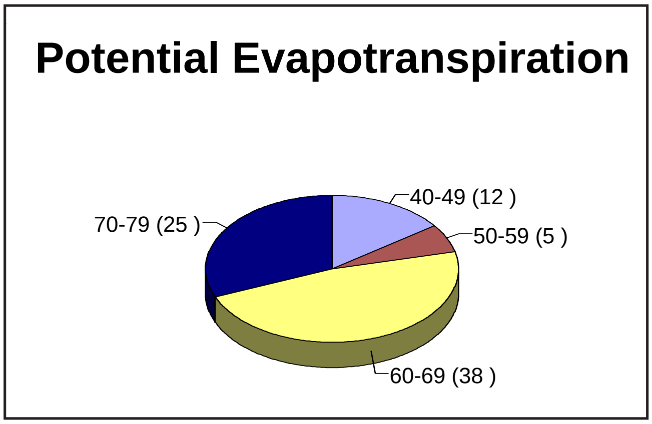

Figure 14.–Number of species (in parentheses) by potential evapotranspiration, mm/month.

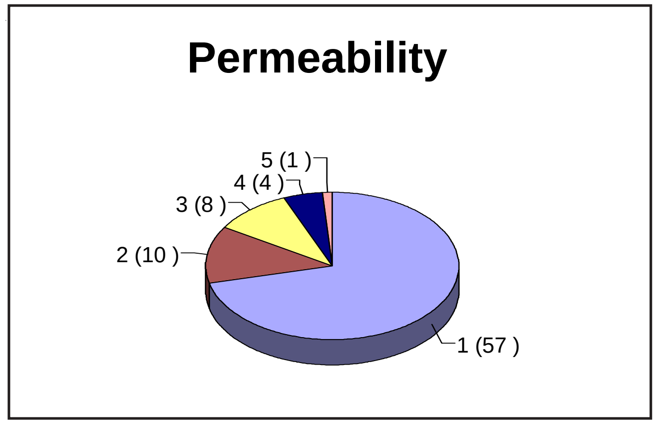

Figure 16.–Number of species (in parentheses) by permeability, cm/hr.

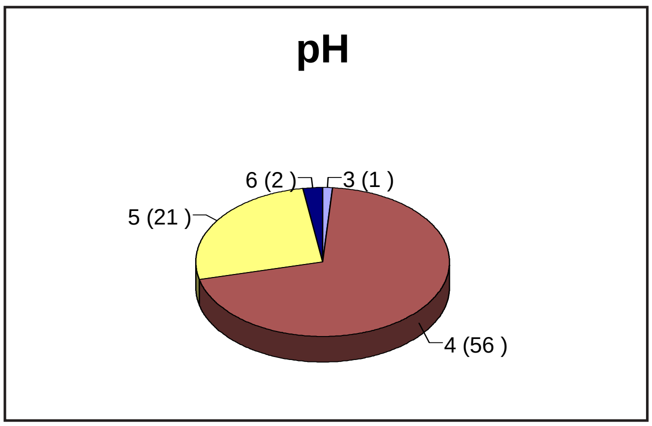

Figure 15.–Number of species (in parentheses) by pH.

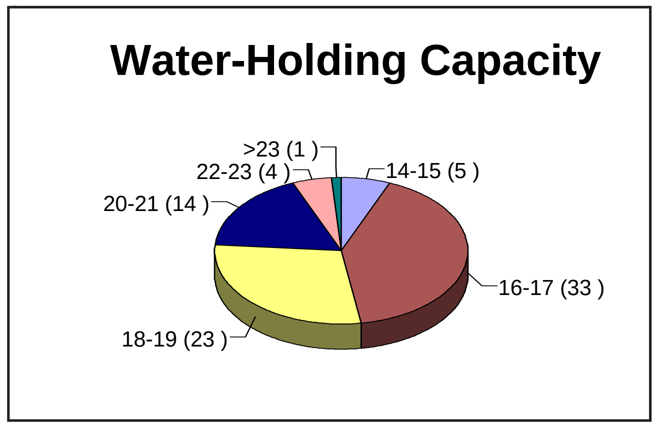

Figure 17.–Number of species (in parentheses) by water-holding capacity, cm water in 152 cm soil column.

Water-Holding Capacity

The water-holding capacity is the amount of water (in cm) the soil can hold to a depth of 152 cm (=5 feet) or bedrock, and is mostly dependent on soil texture, soil organic content, and depth. The range among the 80 species is 14 to 24 cm (Fig. 17). Species at the low end include *Acer pensylvanicum*, *Betula lenta*, and *Tsuga canadensis*, which occupy coarse, shallow soils. At the other extreme are *Quercus macrocarpa* and *Populus deltoides*, which are western species occupying deep, loamy, and organically rich soils, including some former prairie soils.

Organic Matter

This variable refers to the median percentage of organic matter (OM) in the surface horizon of soil. It ranges over the 80 species from 1.6 percent for *Quercus phellos* to 7.7 percent for *Abies balsamea* and 8.8 percent for *Thuja occidentalis* (Fig. 18). The latter two species prefer to grow in low, swampy (=high OM) forests. Sixty-three species have median OM percentages below 3.0 percent, with the overall mean being 2.6 percent. Higher values (>3.0%) tend to exist for species that occur in counties with significant peat content or prairie soils. The overall weighted-average OM in a particular county may be skewed higher if the county contains significant peat deposits, yet the species itself may not occur directly in the peat. This may be true for *Pinus resinosa*, which has a median OM of 5.5 percent, yet prefers to grow on rolling hills, probably adjacent to the swamps occupied by *Abies balsamea* and *Thuja occidentalis.*

Clay

Percent clay gives an indication of the texture of the soil, the capability to hold and infiltrate water, and the tendency for the soil to crack or create hardpans upon drying. The range in percent clay is 8.9 for *Abies balsamea* to 28.1 for *Maclura pomifera* (Fig. 19). Fifty-nine species fall in the 21 to 25 percent clay range.

Slope

Slope refers to the average percent slope occurring in the county where the tree species is located, and has a range of 1.7 to 16.2 percent (Fig. 20). There are several species that occur in very flat, swampy areas, with average slopes < 4.0 percent. These include *Nyssa aquatica*, *N. sylvatica* var. *biflora*, *Taxodium distichum*, *T. distichum* var. *nutans*, *Pinus elliottii*, and *P. palustris*. At the other end of the spectrum, several species are mostly found in steep counties with average slopes > 14.0 percent, including *Acer pensylvanicum*, *Betula lenta*, *Pinus virginiana*, and *Quercus prinus*.

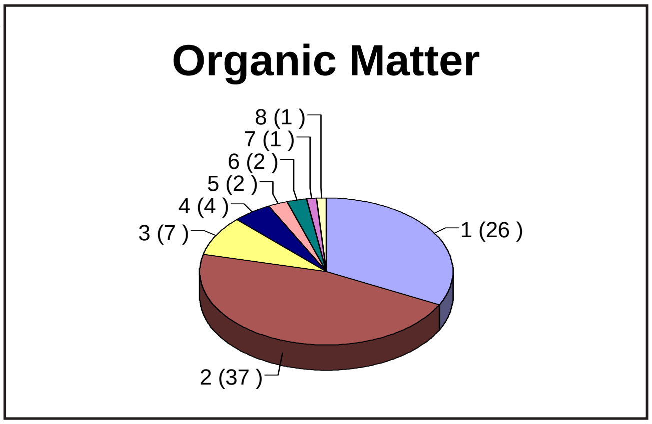

Figure 18.–Number of species (in parentheses) by organic matter, percent by weight.

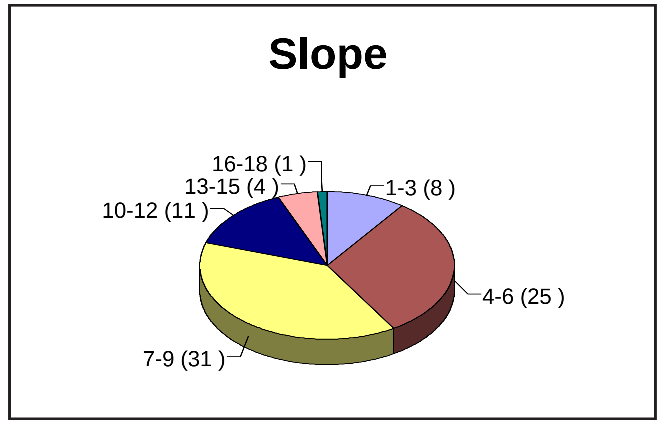

Figure 20.–Number of species (in parentheses) by slope, percent.

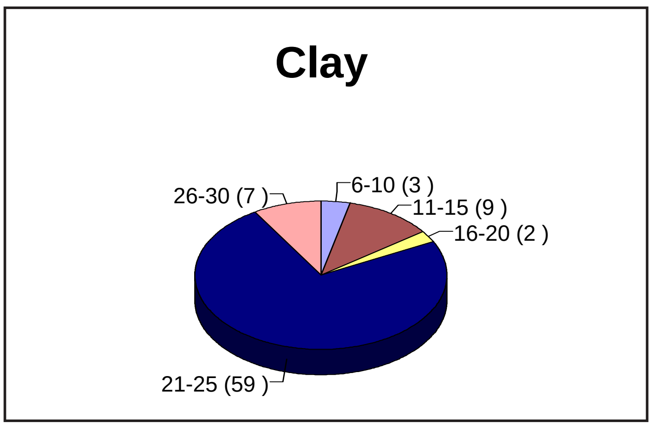

Figure 19.–Number of species (in parentheses) by clay, percent.

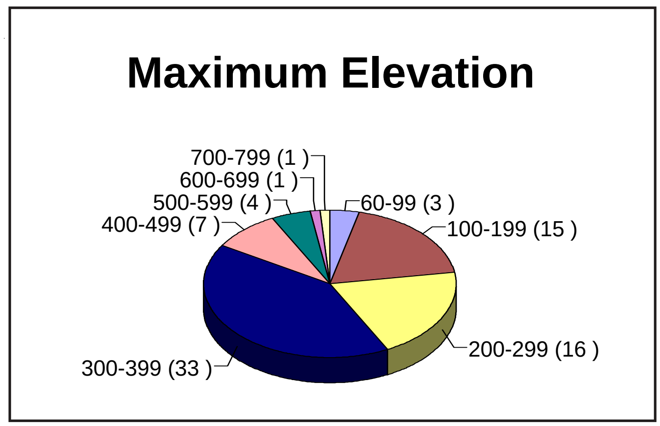

Figure 21.–Number of species (in parentheses) by maximum elevation in the county, m.

Maximum Elevation
This variable is the value of the highest point in the county, as determined from a digital elevation model (1:250,000 scale); a map of maximum elevation is shown in Fig. 1. The range is 62 to 786, and the overall average is 306 (Fig. 21). Three species occupy counties that average < 100 in maximum elevation (in the Gulf Coast area): *Nyssa aquatica*, *Taxodium distichum*, and *T. distichum* var. *nutans*. Only two species (*Betula lenta* and *Acer pensylvanicum*) exist in counties that average above 600 in maximum elevation.

Shade Tolerance
This variable refers to the capacity to survive and grow in the understory beneath a shading canopy. Of the 80 species 26 are tolerant or very tolerant of shade, 27 are intolerant or very intolerant of shade, and 27 more are intermediate in shade tolerance (Fig. 22). Examples of very intolerant species include *Pinus resinosa* and three species of *Populus*, and very tolerant species include *Cornus florida, Carpinus caroliniana, Ostrya virginiana, Abies balsamea,* and *Tsuga canadensis*.

Canopy Trees
Of the 80 species, 69 are considered canopy trees, whereas 11 are seldom in the canopy (not pictured). Understory trees include *Acer pensylvanicum, Carpinus caroliniana, Cercis canadensis, Cornus florida, Crataegus* spp., *Ilex opaca, Maclura pomifera, Morus rubra, Ostrya virginiana, Quercus marilandica,* and *Salix* spp.

Maximum Height
Fourteen species have maximum heights 40 m or higher, and an additional 15 had maximum heights below 20 m (Fig. 23). Most of the shorter trees are listed above as understory trees. A few of the tallest trees include *Populus deltoides, Liquidambar styraciflua*, and *Liriodendron tulipifera*.

Typical Longevity
Roughly 25 species typically live at least 200 years (Fig. 24). The longest lived tree is *Tsuga canadensis*, which typically lives 450 years; other species that typically live at least 300 years are *Fagus grandifolia, Quercus prinus, Q. alba, Thuja occidentalis, Pinus palustris,* and *Acer saccharum.*

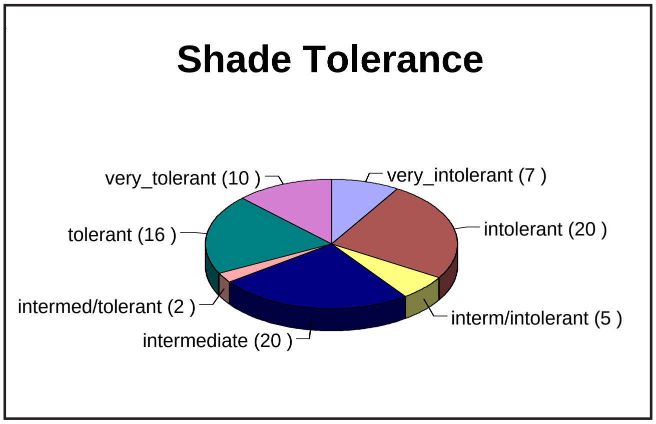

Figure 22.–Number of species (in parentheses) by shade tolerance class.

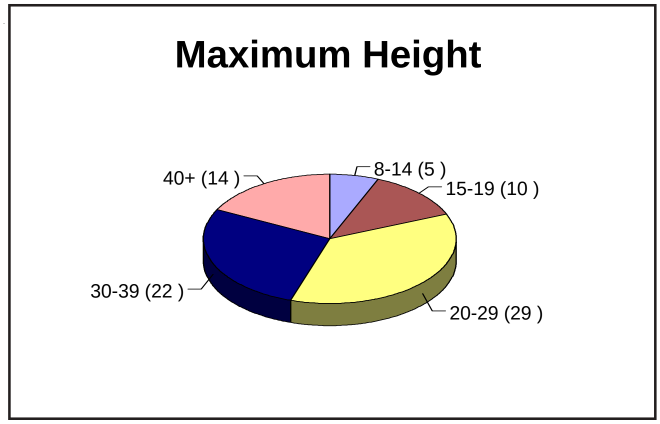

Figure 23.–Number of species (in parentheses) by maximum tree height, m.

Maximum Longevity
Four species are known to have lived at least 500 years: *Tsuga canadensis* (800 years), *Quercus alba* (600), *Sassafras albidum* (500), and *Platanus occidentalis* (500) (Fig. 25). About half can live 100 to 250 years. For another 13 species, we do not know their maximum longevity. Two species (*Salix nigra* and *Celtis occidentalis*) seldom reach 100 years.

Pollination Agent
Most of the species, 61 in all, are wind pollinated, 13 are pollinated by insects, and an additional 6 use either wind or insects (Fig. 26). Some of the insect-pollinated species include *Cercis canadensis, Cornus florida, Crataegus* spp.*, Diospyros virginiana, Gleditsia triacanthos, Liriodendron tulipifera, Magnolia virginiana, Prunus serotina, Sassafras albidum* and *Tilia americana.*

New Cohorts Source
This variable refers to the way in which a new stand can develop. Most species (66) regenerate via seeds or sprouts, which gives maximum flexibility to reproduction (Fig. 27). Some species, such as species from *Populus*, rarely reproduce via seed, but depend primarily on sprouts. Two species, *Fagus grandifolia* and *Robinia pseudoacacia*, use root suckering as their primary means of regeneration. Another 12 species, including nearly all conifers, reproduce exclusively from seeds.

Seed Type
Seed types are numerous, but can be grouped into eight classes (Fig. 28). Most common is the winged type, with 28 species, followed by the nut type, with 23 species. One taxa, *Crataegus* spp., has a pome (apple-like), and another three species (*Gleditsia triacanthos*, *Robinia pseudoacacia*, and *Cercis canadensis*) have pods. Plumed seeds, from the poplars and willows, tend to travel great distances in the wind. The five species in the ‘other’ category include seeds as a berry, berrylike cone, hairy achene, or drupelike follicle.

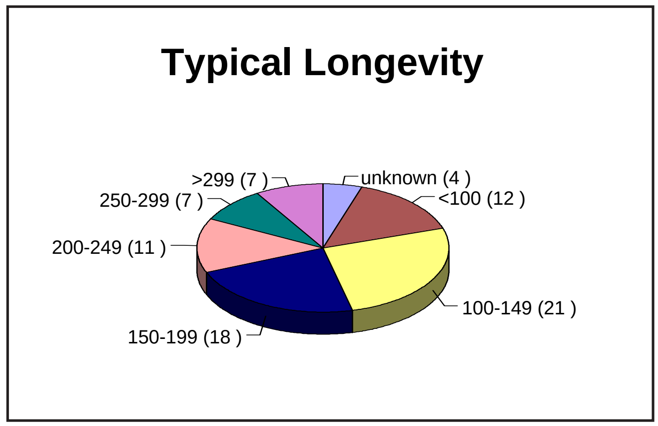

Figure 24.–Number of species (in parentheses) by typical longevity, years.

Dispersal Distance
This distance is the typical distance the seeds disperse from the tree (Fig. 29). Of course, long-distance events can occur on occasion, which may indeed be more critical with respect to migration. Seven species can typically disperse their seeds more than 200m; these are the species with plumed seeds (*Populus* spp., *Salix* spp.), a hairy achene (*Platanus occidentalis*), or a buoyant seed dispersed by water (*Taxodium* spp.). Fifteen species typically disperse their seeds up to 200 m, and another 20 disperse up to 100 m; these are typically seeds with wings, which are typical for the ashes and maples. Finally, another 30 species typically disperse less than 50 m; these are dominated by large-seeded species like oaks, hickories, and walnuts.

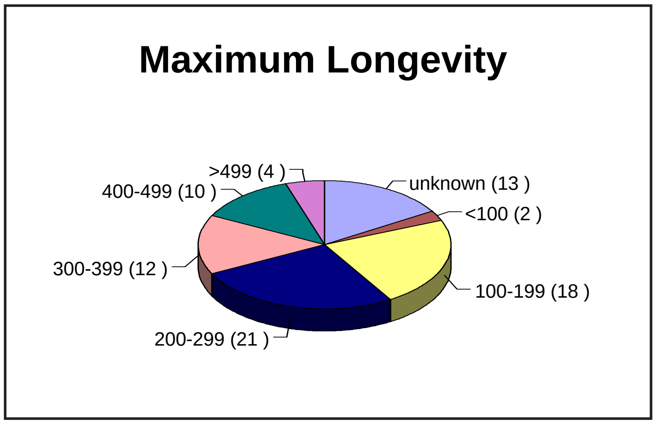

Figure 25.–Number of species (in parentheses) by maximum longevity, years.

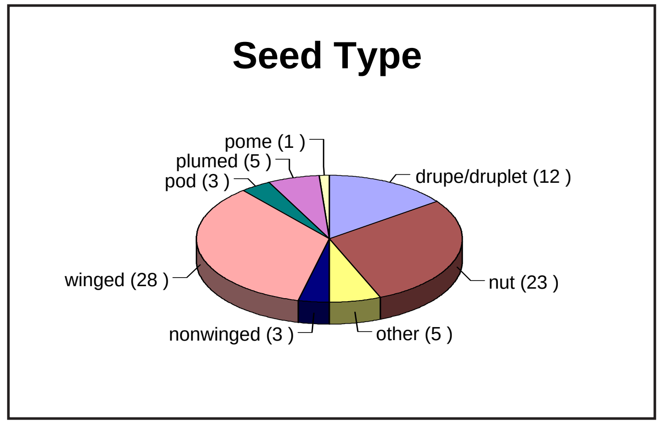

Figure 28.–Number of species (in parentheses) by seed type.

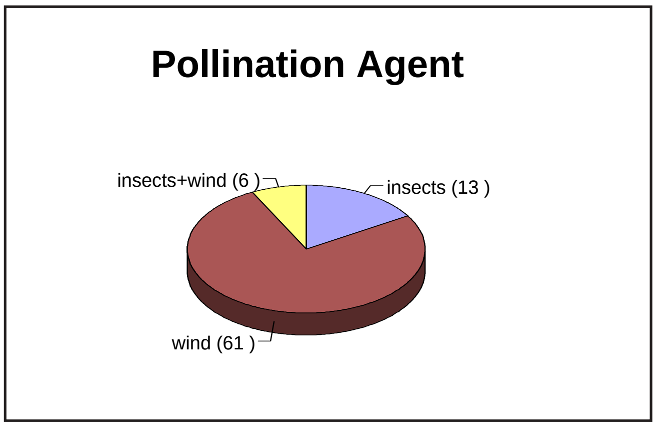

Figure 26.–Number of species (in parentheses) by pollination agent.

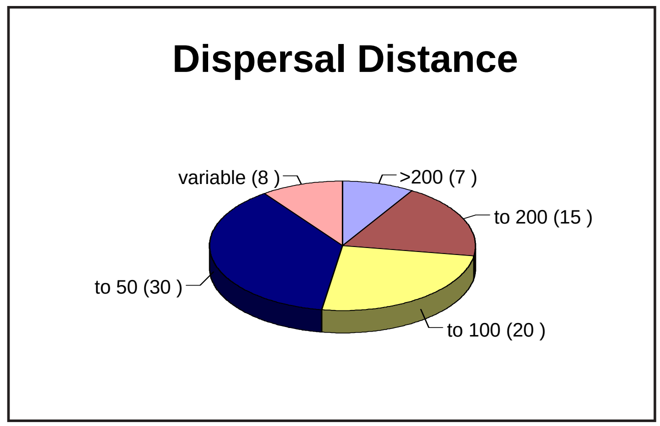

Figure 29.–Number of species (in parentheses) by dispersal distance for seeds, m.

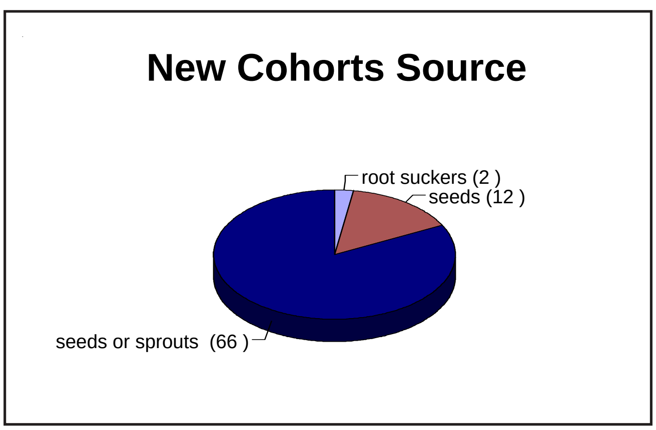

Figure 27.–Number of species (in parentheses) by source of new cohorts.

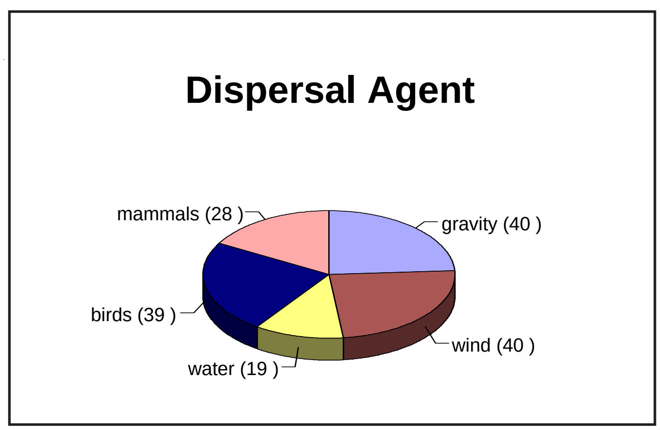

Figure 30.–Number of species (in parentheses) by dispersal agent of seeds.

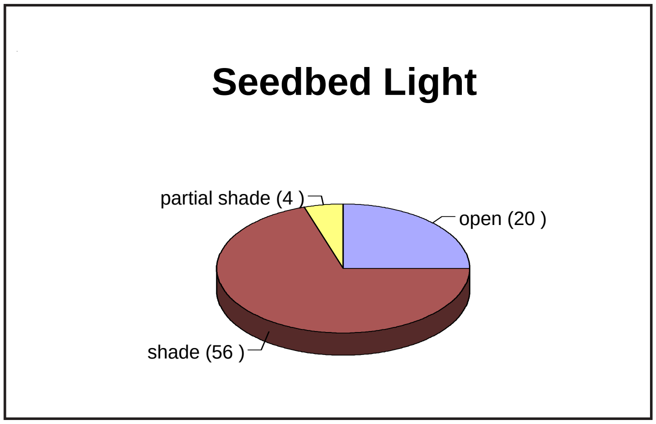

Figure 31.–Number of species (in parentheses) by requirements for seedbed light for germination.

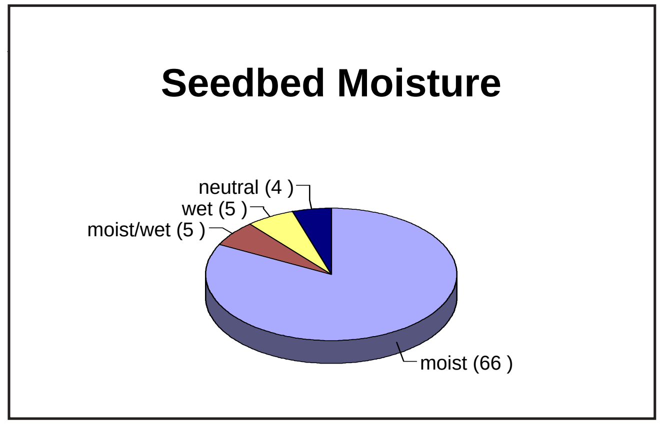

Figure 33.–Number of species (in parentheses) by requirements for seedbed moisture for germination.

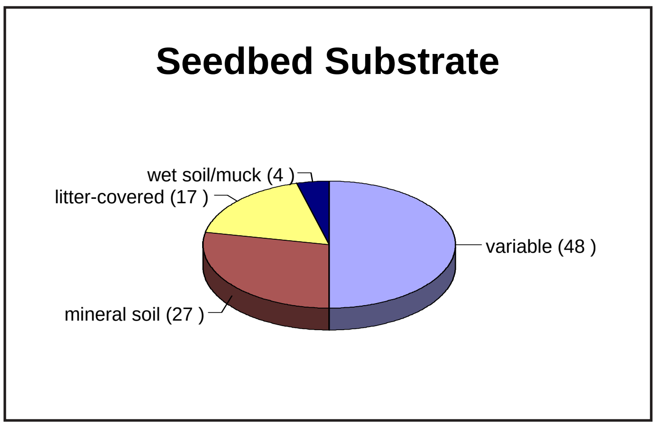

Figure 32.–Number of species (in parentheses) by requirements for seedbed substrate for germination.

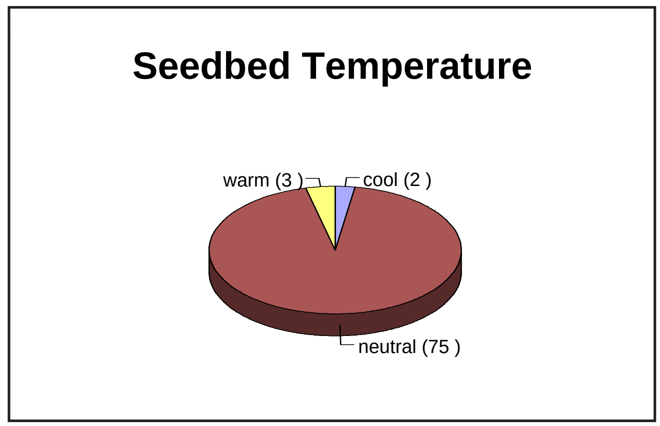

Figure 34.–Number of species (in parentheses) by requirements for seedbed temperature for germination.

Dispersal Agent

Species often use more than one dispersing agent, so the chart has much higher totals (Fig. 30). Forty species use gravity as a primary dispersing agent; these are mostly the species producing nuts such as oaks and hickories, which also use birds and mammals (small rodents) to disperse. Another 40 species use wind (and mostly only wind) as their dispersing agent; these are light-seeded species like *Populus* spp. and *Salix* spp. Nineteen species also use water, such as streams, to disperse their seeds. Finally, birds are also very important and potentially long-distance dispersing agents, being used by 39 species.

Seedbed Preference-Light

This variable refers to the preferred light environment for germination (Fig. 31). The majority of species (56) prefer germinating under shaded conditions, whereas another 20 prefer or require open conditions to germinate.

Seedbed Preference-Substrate

This variable reflects the substrate preference of the species for germination of seeds, and more than one preference is possible (Fig. 32). Nearly half of the species have variable substrate requirements to germinate, which means that given other suitable conditions, the species may germinate under a variety of substrate conditions. Other species have more specific requirements. For example, four species from the genera *Nyssa* and *Taxodium* prefer wet or muck soils to germinate.

Seedbed Preference-Moisture

Most all the species require a moist substrate for germination (Fig. 33). Five species require very wet conditions (*Nyssa* spp., *Taxodium* spp., *Populus deltoides*) to germinate, and four species are relatively neutral with respect to moisture requirements *(Pinus palustris, Quercus alba, Q. marilandica,* and *Q. prinus*).

Seedbed Preference-Temperature

Seedbed temperatures do not seem to matter much relative to other seedbed requirements, 75 of the 80 species have neutral temperature requirements for germination (Fig. 34). Only two species (*Quercus alba* and *Acer saccharum*) prefer cooler soils, and three species (*Betula alleghaniensis*, *Thuja occidentalis*, and *Tsuga canadensis*) prefer relatively warmer soils for germination.

Change in Area
With this variable, we evaluate the potential change in area, in percent, that could result from climate change, according to two 2xCO_2 equilibrium models, GISS and GFDL (Figs. 35-36). Species projected to lose at least 90 percent of their area from the eastern United States, according to the GISS model, include *Thuja occidentalis, Populus grandidentata,* and *Abies balsamea*. The GFDL scenario creates a more harsh environment, with six additional species projected to lose 90 percent or more of their area: *Acer saccharum, Populus tremuloides, Betula alleghaniensis, B. papyrifera, Pinus resinosa,* and *Fagus grandifolia.* At the other end of the spectrum, the following seven species could potentially increase their area by at least 75% under both global change scenarios: *Celtis laevigata, Carya tomentosa, Ulmus alata, Quercus marilandica, Q. phellos, Q. laurifolia*, and *Q. nigra*.

Change in Area-Weighted Importance Value
This variable relates to the potential percentage change in area-weighted IV for the species, according to GISS and GFDL scenarios (Figs. 37-38). The nine species mentioned above as showing a large potential decrease in area also show large potential decreases for this metric, but two other species with at least a 75% decrease in area-weighted importance value are *Acer pensylvanicum* and *Pinus virginiana*. Species that show large potential increase (> 100% increase for both scenarios) in weighted average IV include *Taxodium distichum* var. *nutans, Ulmus alata, Celtis laevigata, Quercus marilandica, Maclura pomifera, Quercus stellata, Quercus falcata* var. *falcata, Pinus palustris, Quercus phellos*, and *Carya tomentosa*.

Possible N-S Change of Northern Front
This variable relates to the potential change in the latitudinal optimum of the northern front for each species (Figs. 39-40). The latitudinal optimum was derived statistically, and was intended to reduce variability due to spurious outlier counties (Iverson and Prasad 1998). Overall, this metric indicates that 24-26 species would not likely shift positions of the optimal latitude (< 10 km either way), while 47 species could potentially migrate north, and 7-9 could move south (Figs. 39-40). Several species could have their optimum latitude shift out of the United States as they migrate into Canada. According to the GISS model, this could happen for *Thuja occidentalis, Betula papyrifera, Pinus resinosa,* and *Abies balsamea*, while with the GFDL model, these four plus four more, *Acer saccharum, Populus tremuloides, P. grandidentata, and Betula alleghaniensis,* could be affected. If the optimum latitude shifts north out of the country, it does not necessarily mean that the species is projected to be completely extirpated from the United States. Other species potentially migrating >300 km north include *Quercus marilandica* and *Cercis canadensis*. Species potentially migrating >100 south include *Acer rubrum, Fagus grandifolia,* and *Crataegus* spp. These species are mostly generalists which had substantial decreases in weighted average importance values, especially in the more northerly locations.

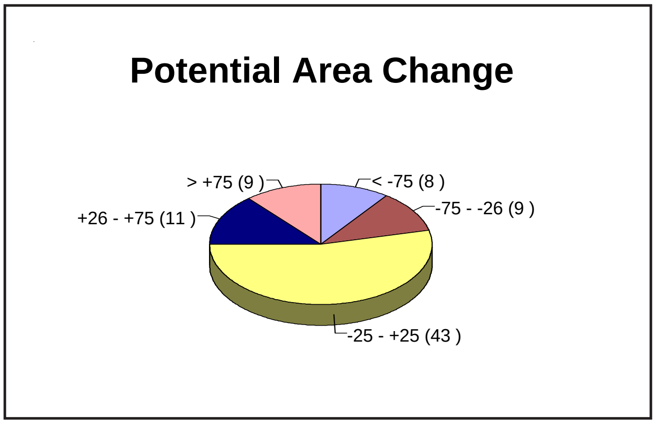

Figure 35.–Number of species (in parentheses) by potential area change, GISS scenario, percent.

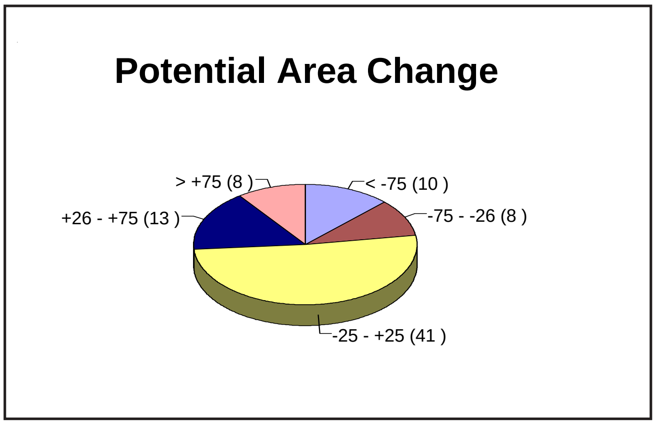

Figure 36.–Number of species (in parentheses) by potential area change, GFDL scenario, percent.

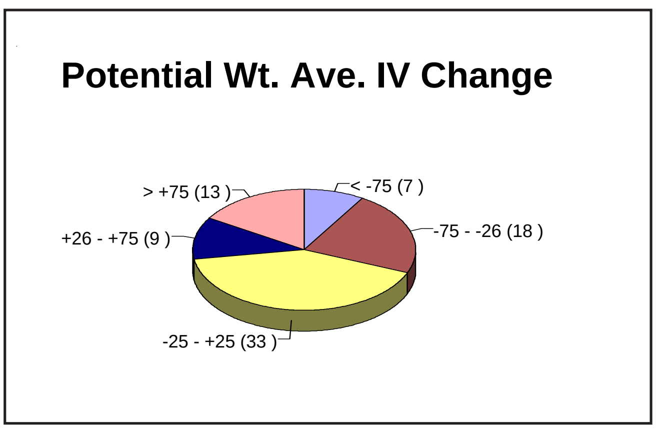

Figure 37.–Number of species (in parentheses) by potential change in weighted average importance value, GISS scenario, percent.

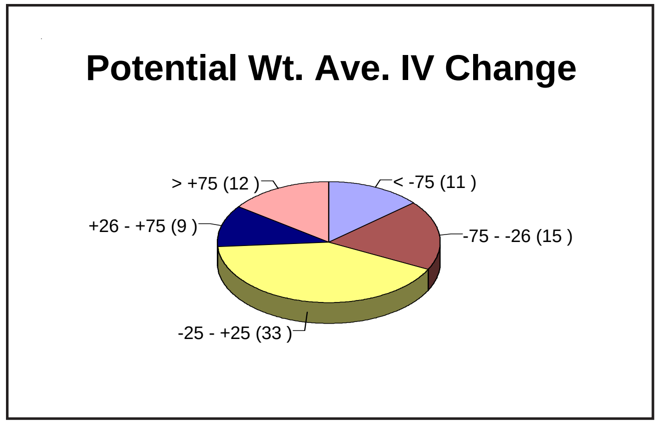

Figure 38.–Number of species (in parentheses) by potential change in weighted average importance value, GFDL scenario, percent.

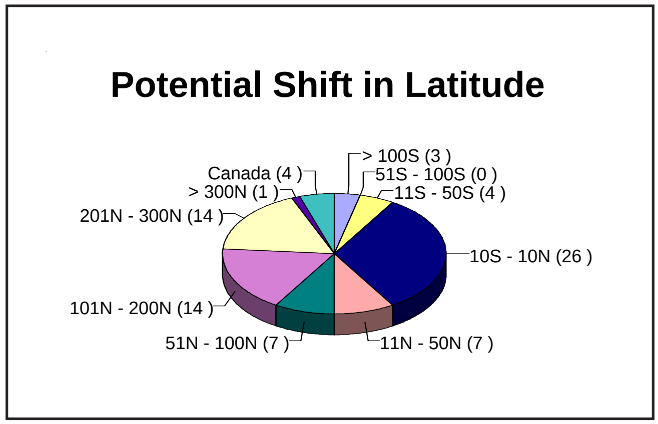

Figure 39.–Number of species (in parentheses) by potential shift of the optimum latitude, GISS scenario, km.

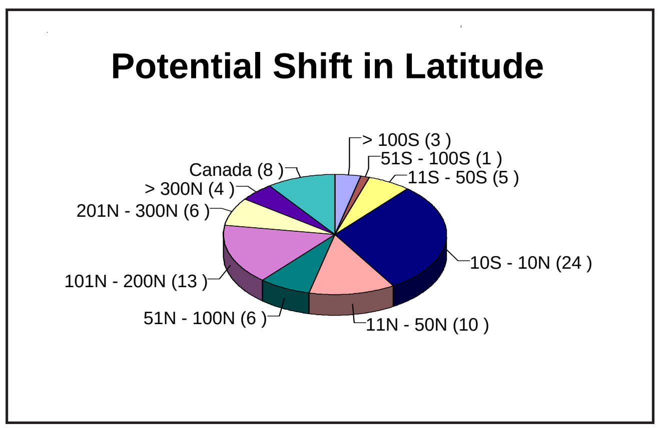

Figure 40.–Number of species (in parentheses) by potential shift of the optimum latitude, GFDL scenario, km.

Part 4--*Appendices*

Part 4--Appendices

Appendix A

Forest Inventory and Analysis Data

Much of the information on the tree species for this atlas was complied from Forest Inventory and Analysis (FIA) data. Six USDA Forest Service FIA units periodically determine the extent, condition, and volume of timber, growth, and removal on the Nation's forest land. Four FIA units produced a data base 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 (Hansen et al. 1992): county data, plot data, and tree data. Plot locations are not precisely located, but county location was provided for each plot. Ideally, we would conduct the research at a finer, regular scale of resolution, but the EWDB data are not amenable to finer processing. We used the data from more than 100,000 plots covering nearly 3 million trees to summarize the desired county-level information needed for this study (Table 2). The number of total plots, forested plots, counties and species, date of inventory, percent forest, land area, and forest area is given for each state in the study area in Table 2. We evaluated 196 tree species from the EWDB, but only 80 species were modeled due to sample restrictions. Nomenclature for the species follows Appendix C in Hansen et al. (1992).

We first summarized the information for individual forested plots. Tree records represented observations of seedlings, saplings, and overstory trees. Tree species, tree status, and d.b.h. were combined with information on plot size to compute a single summary record for each plot. This record contained, by species, estimates of the average number of stems and total basal area of understory and overstory trees per unit area. From this information, we generated importance values (IV) for each species as follows:

$$IV(x) = \frac{100BA(x)}{BA(allspecies)} + \frac{100NS(x)}{NS(allspecies)}$$

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

To aggregate plot-level information to the county level, no GIS processing was necessary until final mapping because each plot has a county code associated with it. Average IV's were calculated for each species at the plot and county levels. These values were associated with a county coverage of the United States (ArcUSA—Environmental Systems Research Institute 1992) for mapping into density slices of IV. By viewing these maps (the upper left map for each species in Part 2--Atlas), biogeographical characteristics (such as absolute and optimum range) of the species can be visualized. The IV was modelled as the response variable in our analysis. These data are also prerequisites for all analysis to follow.

Table 2.—Summary of FIA data by state.

State	Number of Forest plots	Number of Plots	Number of Species	Number of Counties	Date, FIA	Forest, %[a]	Land, acres[a]	Forest, acres[a]
Alabama	3,923	4,515	117	67	1990	67.7	32,480	21,974
Arkansas	3,073	3,785	105	75	1988	53.6	33,328	17,864
Connecticut	286	463	61	8	1984	58.7	3,101	1,819
Delaware	151	250	59	3	1986	31.1	1,251	389
Florida	6,061	13,712	68	67	1987	47.9	34,558	16,549
Georgia	7,713	12,015	84	160	1989	65.1	37,068	24,137
Illinois	1,169	10,957	86	102	1985	12.0	35,580	4,266
Indiana	2,140	11,440	94	92	1986	19.3	22,957	4,439
Iowa	713	12,767	63	99	1990	5.7	35,760	2,050
Kansas	1,070	23,705	52	105	1981	2.6	52,367	1,359
Kentucky	1,950	3,049	107	120	1987	50.0	25,429	12,714
Louisiana	2,414	2,893	99	64	1991	49.7	27,882	13,864
Maine	2,161	2,483	62	16	1994	88.8	19,753	17,533
Maryland	726	1,199	98	23	1985	42.9	6,295	2,700
Massachusetts	380	555	71	14	1984	63.9	5,016	3,203
Michigan	10,849	18,484	81	83	1980	50.2	36,358	18,253
Minnesota	13,511	43,957	60	87	1990	32.8	50,955	16,718
Mississippi	3,188	5,376	104	82	1987	56.6	30,025	17,000
Missouri	5,077	17,270	90	115	1989	31.8	44,095	14,007
Nebraska	216	14,449	40	93	1983	1.5	49,202	722
New Hampshire	590	697	58	10	1983	86.8	5,740	4,981
New Jersey	255	644	77	21	1986	42.3	4,748	2,007
New York	3,100	5,403	86	62	1993	61.9	30,223	18,713
North Carolina	6,035	10,018	90	100	1990	61.8	31,180	19,278
North Dakota	239	18,214	24	53	1980	1.0	44,156	462
Ohio	1,710	4,845	104	88	1990	30.0	26,210	7,863
Oklahoma	902	1,107	80	77	1986	17.2	43,954	7,539
Pennsylvania	3,142	5,298	103	67	1990	59.2	28,685	16,969
Rhode Island	116	179	46	5	1984	59.9	669	401
South Carolina	4,511	7,031	85	46	1986	63.6	19,271	12,257
South Dakota	166	23,206	23	66	1980	3.5	48,575	1,690
Tennessee	2,316	2,950	113	95	1989	51.6	26,380	13,612
Texas	2,090	3,815	99	254	1986	11.4	167,625	19,193
Vermont	626	823	61	14	1983	76.7	5,920	4,538
Virginia	4,260	7,312	87	95	1992	62.6	25,343	15,858
West Virginia	2,572	3,169	109	55	1988	78.7	15,415	12,128
Wisconsin	6,939	15,908	67	72	1983	44.6	34,761	15,513

[a]Forest percent, and acreage estimates are from Powell et al. (1993).

Appendix B

Environmental Data

Data were extracted from several sources for land east of the 100th meridian. The county was chosen as the mapping unit because it is the reporting unit for many sources of data and, for the most part except for some northern counties, has roughly the same area across the study region. We evaluated more than 100 environmental/land use/socioeconomic variables for each of nearly 2,500 counties in the East. Because of missing FIA information, only 2,124 counties were finally mapped. To reduce autocorrelation and enable better interpretation, the final number of variables was reduced to 33 (Table 1) by: (a) removing highly redundant variables as deduced by correlation analysis; (b) dropping variables selected by experts as excessively difficult to interpret; and (c) scoring 65 variables for their value in an earlier RTA run on all species and dropping the variables of lower importance. To evaluate overall importance of each of the resulting 33 variables, they were scored for frequency of occurrence and rank-based weight in the RTA outputs for the 80 species (Table 1).

Variables fall into one of several classes: climatic, soil, land use/cover, elevation, and landscape pattern:

Climatic factors. — Monthly means (averaged from 1948-1987) of precipitation, temperature, and potential evapotranspiration for the current climate were extracted from a data base generated by the USEPA (1993). The data had been interpolated into 10- x 10-km grid cells for the conterminous United States. From these data, we extracted January and July temperatures, calculated annual means, and derived two attributes based on their physiological importance to tree growth for this region: July-August ratio of precipitation to potential evapotranspiration (the time most prone to drought stress in the Eastern U.S.), and May-September (that is, growing season) mean temperature. The data were then transformed to county averages via area-weighted averaging.

Two scenarios of future monthly temperature and precipitation under an equilibrium state of 2xCO_2 were used for predictions of potential future species distributions: the Geophysical Fluid Dynamics Laboratory (GFDL) (Wetherald and Manabe 1988) and Goodard Institute of Space Studies (GISS) (Hansen et al. 1988) models, which depict a different set of outcomes. These GCM output data were also prepared by USEPA (1993) into future equilibrium estimates, by 10- x 10- km grid, for monthly precipitation, temperature, and potential evapotranspiration.

We also calculated the two derived variables related to tree growth using these data.

Soil factors.— The State Soil Geographic Data Base (STATSGO) was developed by the U.S. Natural Resource Conservation Service to help achieve their mandate to collect, store, maintain, and distribute soil-survey information for U.S. lands. STATSGO data contain 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 (1:250,000) more appropriate for regional analysis. We selected 14 soil variables related to tree species' habitat (Table 1). Weighted averages by depth and by area were calculated for county estimates of the soil variables, as detailed in Iverson et al. (1996). Additional soil information was obtained from the GEOECOLOGY databases (Olson et al. 1980), including percentage of the county in each of four soil orders (Table 1).

Land use/cover factors.— GEOECOLOGY (Olson et al. 1980) data were used for estimations of percent forest, crop, grazing/pasture, and disturbed land (Table 1). These estimates originated from the USDA Soil Conservation Service's National Resources Inventory for 1977.

Elevation.— Maximum, minimum, and variation of elevation were derived for each county from 1:250,000 U.S. Geological Survey (USGS) Digital Elevation Model (DEM) files obtained from the USGS internet site (U.S. Geological Survey ongoing).

Landscape pattern.— The 1-km Advanced Very High Resolution Radiometer (AVHRR) forest cover map (USDA Forest Service 1993) was used to generate statistics on forest-cover pattern by county. Several landscape pattern indices were calculated using FRAGSTATS (McGarigal and Marks 1995), but only edge density was used in the final analysis.

Selected input variables are presented in Figure 1 to show the distribution across the Eastern United States. Six variables are presented that represent each of the major groups of variables in the analysis.

Appendix C

Regression Tree Analysis

We used regression tree analysis, or RTA, (also known as classification and regression trees) to decipher the relationships between environmental factors and species distribution. RTA is a recursive data partitioning algorithm that initially splits the data set into two subsets based on a single best predictor variable (the variable that minimizes the variance in the response). It then does the same on each of the subsets and so on recursively. The output is a tree with branches and terminal nodes. The predicted value at each terminal node is the average at that node, which is relatively homogeneous (Clark and Pregibon 1992).

There are several key advantages to using RTA in this application, which covers such a wide spatial domain, over classical statistical methods (Clark and Pregibon 1992, Breiman et al. 1984, Michaelsen et al. 1994). First, RTA is adept at capturing nonadditive behavior, where relationships between the response variable and some predictor variables are conditional on the values of other predictors. For example, in our study, the factors associated with the northern range limits for a species may be quite different from the factors regulating the southern limit of the species. This advantage allows, in effect, a stratification of the country so that some variables may be most related to the IV of species A for a particular region of the country, but a different set of variables may drive its importance elsewhere. Second, numerical and categorical variables can easily be used together and interpreted, because RTA essentially converts continuous data into two categories at each node. The outcome is a set of step functions that provides a better capturing of non-linear relationships, while also providing a reasonable solution for linear relationships. Last, the variables that operate at large scales are used for splitting criteria early in the model, while variables that influence the response variable locally are used in decision rules near the terminal nodes (Moore et al. 1991). Thus, we could expect that broad climatic patterns are captured higher up on the tree diagram, while more local effects (soil, elevation, etc.) determine more local distributional variations. It should, however, be recognized that because our data set is aggregated to a county-level scale, RTA cannot capture the environmental drivers that operate on species at a very fine scale (for example, individual slopes or valley bottoms).

There are limitations of RTA, however. The response variable (IV, in this instance) ideally should be approximately normal, since least squares and the group mean are used in deriving the best split (Clark and Pregibon 1992). Even though the IV response in our example more closely resembles a Poisson distribution due to the high frequency of zeros, the effect of long tails is much more confined than in a linear regression model as the regression is local (B.D. Ripley, personal communication). We take a further step and predict the effect of a changed climate based on the model. Although there is danger of extrapolating the results beyond the model's predictive ability for some species, it does provide a reasonable estimate of the species' potential migration under changed climatic conditions, whose preferences we know *a priori*.

Regression trees were generated in S-PLUS (Statistical Sciences 1993) using the RPART module developed by researchers at Mayo clinic (Therneau and Atkinson 1997). Species IV (based on basal area and number of stems) was the response variable, with the 33 predictor variables (see Table 1). The regression trees were generated on a split data set — a random selection of 80 percent of the data — so that 20 percent of the data remained for validation efforts (Iverson and Prasad 1998). RTA models were generated after pruning the full tree to 12 to 20 nodes, depending on the Cp statistics. When an additional split did not improve the overall R^2 of the model by at least Cp, the RTA model building was stopped. The resulting model was used to generate predictions of IV of each species for each county.

The response predicted by RTA for zero values of IV was nearly always a fraction less than one. By testing across all species, we determined that predicted IV scores less than the threshold of ~1.0 were essentially zero and were set as such. This threshold varied slightly for some species to achieve a better fit of predicted presence/absence to the actual FIA data. The predictions of IV classes were then output to Arc/Info for mapping using Unix tools and Arc/Info's Arc Macro Language (Environmental Systems Research Institute 1993).

Once the regression trees were generated, they were used to generate not only predictive maps of current distributions, but also potential future distributions under a scenario of a changed climate. We did this by replacing the climate-related variables in our predictor variable set with those based on the GFDL and GISS models. The replaced variables were (see Table 1 for the description): MAYSEPT, JARPPET, JANT, JULT, AVGT, PET, and PPT. The previously established regression trees then were used with the new predictive variables, and the data output to Arc/Info as before.

Modeling Assumptions

Several assumptions were made in this model; each of which add uncertainty to the outcomes. As further research is conducted that will eliminate the need for these assumptions, uncertainty can be reduced. First, uncertainty remains in projected climate change under a doubled CO_2 scenario, especially as it plays out spatially across the continent. The impacts of this uncertainty on our results is reduced by using two scenarios, but changes in estimates of future climate will continue to occur. In fact, more recent and slightly different GCM scenarios have been produced since this modeling effort was conducted (see *www.fs.fed.us/ne/delaware/atlas*).

Second, any time multiple GIS layers from disparate sources and scales are overlaid, errors will propagate through the data (Goodchild and Gopal 1989). This impact is minimized in this study by using a large sampling unit, the county, as the common spatial unit. However, some counties are very diverse, and some important ecological factors could be model outputs. Therefore, there is no way to assess changes in competition among the 'new' species mix, nor is there a way to account for whatever gains in water-use efficiency may accompany elevated CO_2 (Neilson 1995).

Fourth, in a criticism of model-based assessments of climate change effects on forests, Loehle and LeBlanc (1996) note that many forest simulation models assume that tree species occur in all environments where it is possible for them to survive, and that they cannot survive outside the climatic conditions of their current range (fundamental vs. realized niche). The RTA models here reduce this problem by considering a wide range of variables and only trying to evaluate potential range changes due to climate change. These models assume equilibrium conditions, and that there are no barriers to migration. Finally, RTA does have limitations, and spurious or non-causative relationships will appear, especially when RTA methodology is applied to 80 species without fine-tuning for individual species preferences. Improvement of models may be possible for many of the species, if individual characteristics and spatial trends are taken into account.

This study, however, conducts an overall assessment of most all the important species in the Eastern United States. We list, by species and for two global change scenarios, potential changes that could result from climate change. We evaluate not only climate variables, but also edaphic, land use, and topographic variables such that environmental barriers are considered in the potential redistribution of species. This framework of potential future suitable habitat can therefore be the starting place for future research on how biological factors interact to produce the species assemblages though these next decades of climate change.

Appendix D

Migration Modeling with Fragmented Habitat

The regression tree models that produced the maps in this atlas produce estimates of potential future distributions according to the GISS GCM scenario. The deterministic model outcomes assume the species will get there if conditions are suitable, and that equilibrium with the new climate has been achieved. In this section, we report on preliminary work using a stochastic model, SHIFT, that incorporates the effects of time and fragmented forest cover to provide a realistic picture of predicted distributions after 100 years. The effort is detailed in a publication by Iverson, Prasad, and Schwartz (Iverson et al., 1999). SHIFT was originally written by Mark Schwartz (Schwartz 1992, 1996) for hypothetical landscapes, and was extended for use across the Eastern United States. We present an example for Virginia pine (*Pinus virginiana*).

With SHIFT, the output of potential future distribution becomes the “envelope” into which the species is allowed to migrate. SHIFT is a spatially explicit, cellular automata simulation model developed to describe a probability distribution for the colonization of currently unoccupied habitats (Schwartz 1992). SHIFT uses three variables (habitat availability, within-stand abundance in occupied cells, and distance between occupied and unoccupied cells) to calculate a colonization probability for each unoccupied cell in each generation of a simulation run. SHIFT minimizes assumptions about and approximations of biologically important variables (for example, seedling establishment, juvenile mortality, interspecific competition) in favor of the simple assumption that species can maintain an average migration rate of 50 km/century in fully forested regions. This rate is the upper end of the range of observed migration rates during the Holocene (Davis 1981, 1989). SHIFT predicts migration rates to slow as habitat availability decreases, leaving fewer colonization opportunities and a greater mean distance between cells. In a hypothetical landscape, migration rates are observed to be as low as 10 km/century when only 20 percent of the landscape remains as suitable habitat (Schwartz 1992). These results do not differ greatly from similar models that have specified more biological variables to predict migration response to habitat fragmentation (for example, Dyer 1994, 1995, Collingham et al. 1996).

The equation SHIFT uses to determine the probability of an unoccupied cell becoming colonized (C_i) is:

$$C_i = H_i \times \Sigma (H_j \times F_j \times k/D_{ij}^{a})$$

where H represents habitat availability in occupied (j) and unoccupied (i) cells, F_j represents the within-stand abundance (IV) of the target population in occupied cells, and D_{ij} represents the distance between occupied and unoccupied cells. SHIFT uses an inverse power parameter (a) of the distance between sites (D_{ij}) to determine colonization probability (Schwartz 1992). This dispersal function was chosen based on fitting of the tails of empirical seed-dispersal data sets (Portnoy and Willson 1993). The inverse power function allows more long-distance dispersal than a negative exponential function, the other commonly used dispersal function. The coefficient (a) was set at 3, which represents a compromise value between empirically fitted data on seed dispersal tails (Portnoy and Willson 1993) and empirical estimates of the proportion of dispersal opportunity that resides in the tail of the distribution (Clark 1998). The calibration constant (k) was determined by calibrating the species to migrate through the habitat matrix at 50 km/century when habitat availability was high (80% of all cells) and forest abundance was moderate.

Habitat availability of occupied (H_j) and unoccupied (H_i) cells was determined by AVHRR-derived forest density (percent forest by AVHRR pixel) (Zhu and Evans 1994), as modified by forest type (that is, extremely high agricultural regions in the Midwest were coded as nonforest). Species abundance of occupied cells (F_j) was estimated from a smoothed IV map derived from FIA data.

SHIFT was run with a grain size of 3 km and with an extent of the Eastern United States, and was run to simulate 100 years, or five generations, based on an estimated average maturation period of 20 years (Altman and Dittmer 1962) for growth of Virginia pine within forested stands. One hundred years also approximates the time projected by the Intergovernmental Panel on Climate Change (IPCC) for the earth to reach $2xCO_2$ (500 ppmv, which approaches twice the preindustrial levels of 280 ppmv (Houghton et al. 1996)). This simulation process was repeated for 50 replications to describe each initially unoccupied cell by a colonization probability over the next century.

Along with its relatively simple math, SHIFT carries several simplifying assumptions. First, we make several assumptions for computational convenience: (a) local extinctions are not possible (these would tend to lower migration rates); (b) habitat is coded simply as a percentage of forested habitat per cell so that variations in forest type or matrix quality are not considered; and (c) colonization is equally likely in all directions from an occupied site. Second, we assume that biological processes, such as species autecologies and interspecific interactions, that gave rise to observed Holocene migration rates continue to dominate migration responses of trees. SHIFT provides no directionality to migration, and is simply a model of migration under an assumption of climatic release.

By combining results from the RTA of future potential distribution and migration (SHIFT), we predict the potential response of Virginia pine to global warming over the next century (Fig. 41). As we have done throughout this atlas, we present its actual FIA estimate of IV (Fig. 41a), its predicted current distribution according to the DISTRIB model (Fig. 41b), and its predicted future potential habitat according to the GISS scenario (Fig. 41d). In addition, the smoothed IV map (Fig. 41c) shows the smoothed estimate of current distribution within the boundaries established by Little (1971). The RTA effort gives those areas where suitable habitat can occur (Fig. 41d), while SHIFT provides a realistic scenario of migration rates over the next century (Fig. 41e). By simply intersecting the results from both models, constraints on future distributions are provided by each model. We, thus, create a plausible prediction of the extent to which the region of climatically suitable habitat will shift and the extent to which this new distribution envelope will be saturated due to species migration through the landscape as it currently exists (Fig. 41f).

Of course, the output is fraught with assumptions and is best viewed as a hypothesis for potential response. This is an important step, however, in that it will guide the scale of empirical studies to examine for global warming responses of trees, and provide early information on forest management. Efforts are underway to produce this analysis for the majority of the species presented in this atlas.

Pinus virginiana

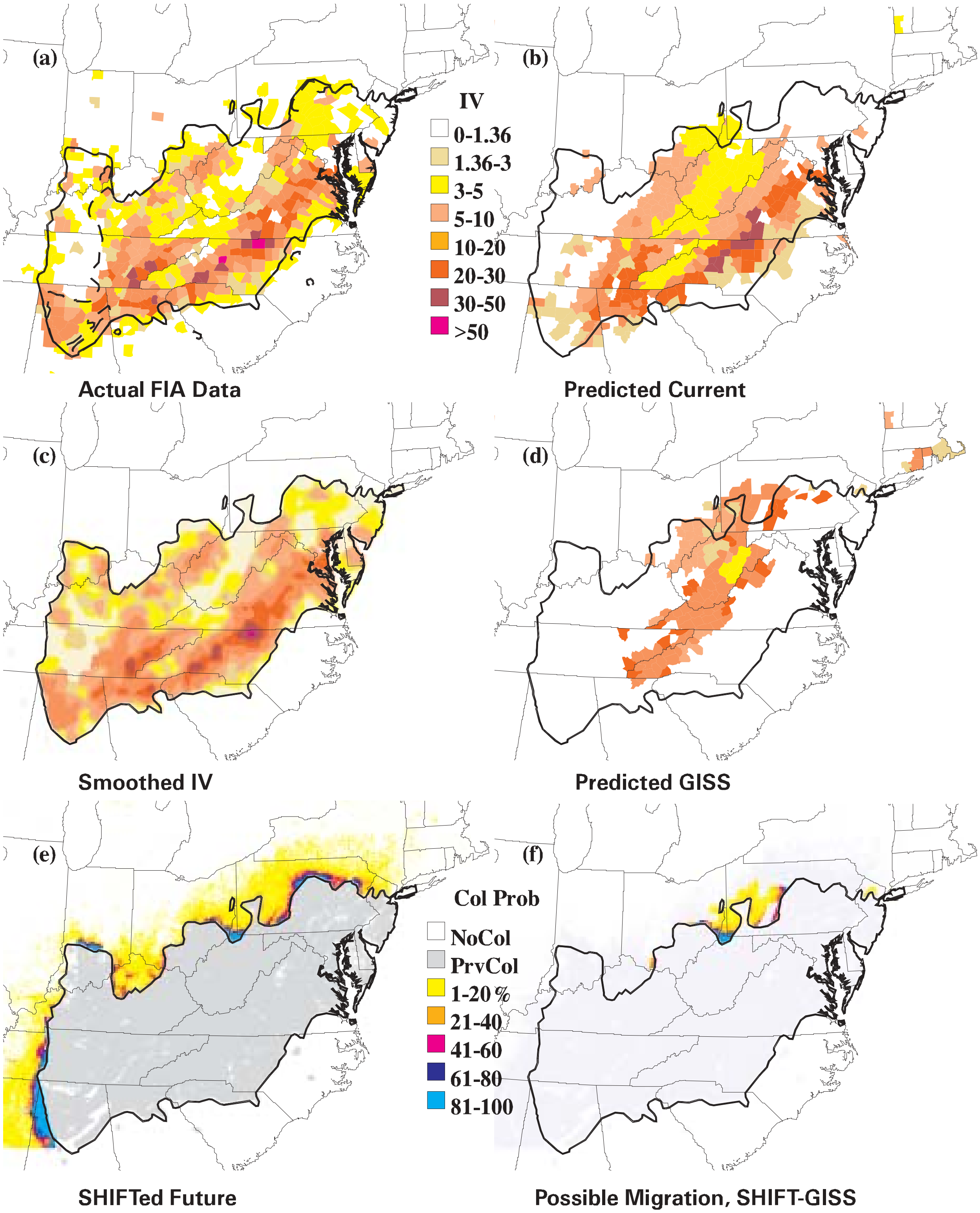

Figure 41.--Outputs for Virginia pine: (a) Actual distribution of importance values, according to FIA data; (b) predicted current distribution according to DISTRIB output; (c) smoothed IV of the species; (d) predicted future distribution, using DISTRIB with the GISS GCM scenario; (e) output from SHIFT, with no restrictions; and (f) output from SHIFT, as constrained by the potential distribution from the DISTRIB-GISS model.

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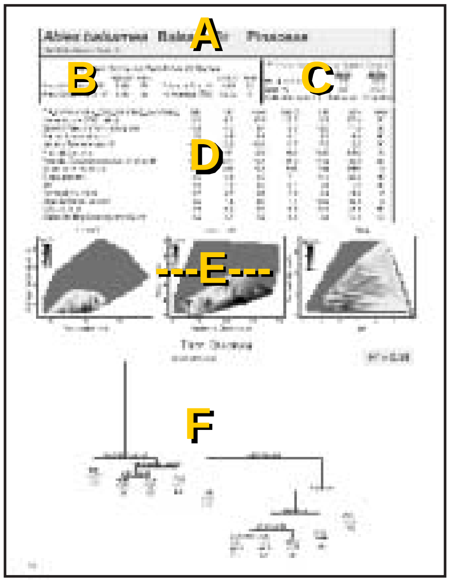
Index of Scientific Names

Page number in **bold** is for map information; number in *italics* is for life history information.

Index of Common Names

Page number in **bold** is for map information; number in *italics* is for life history information.



Summary Data Page

(See pages 7-9 for further explanation)

A. ***Names—***The scientific name, common name, and the family of the species. Also shown is the page number for the life history information on this species.

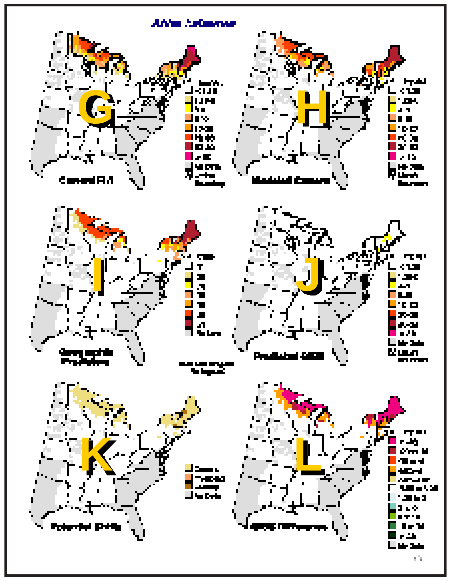
B. ***Current Status and Rank–***Data on the amount and rank (among the 80 species) of area and importance for each species. **Area (FIA)** and **Area (Little)** correspond to areal estimates according to two different data sources, the **average IV** (importance value) relates to average importance of the species across its range, and **∑Area x IV** is an overall measure of prominence by summing the area x IV for each county.

C. ***Potential Change from Climate Change–*** Data for the estimated potential changes that could occur due to a changed climate, according to two global climate change scenarios (GISS=Goddard Institute of Space Studies, GFDL=Geophysical Fluid Dynamics Laboratory). **Weighted IV, %** reflects the potential change (%) in area-weighted importance value, **Area, %** relates to the potential change in area for the species, and **Optimal Latitude, km** reflects potential changes in the species' optimum IV latitudinally (km shift North or South, or it is extirpated from the continental United States).

D. ***FIA Distributions–***Data describe the nature of the distribution for several variables where the species is present, according to the FIA (Forest Inventory and Analysis) data of the USDA Forest Service. Shown are the absolute minimum, the first quartile (25th percentile) of data, the mean, the median (second quartile or 50th percentile of data), the third quartile (75th percentile), the absolute maximum data point, and the rank of this species' median relative to the other 79 for this variable. The median is, therefore, the midpoint of the data, and can be coarsely construed as the optimum point for the species. Variables are explained on page 7 of the text.

E. ***Climate, Landform, and Soil Diagrams***–The dark gray area encompasses the range of selected variables for all species in the Eastern United States. The shaded gray scale within the dark gray area shows the IV for the species within the overall space. Because all species graphs are scaled the same, rapid comparisons can be made among species for their relative relationships to **climat**e (average temperature vs. precipitation), **landform** (slope vs. elevation), and **soil** (permeability vs. pH).

F. ***Tree Diagram***—This diagram is the output from the RTA (explained in Appendix C), and is the basis for prediction of current and potential future distributions of IV. By following a branch with the current (or predicted future) variables for a county, one can predict the IV for the species (shown at the terminal node of the branch, along with the number of counties for that branch and the class for mapping). The bracketed numbers at the bottom are keys to the legend for the map of geographic predictors on the center left of the facing page. Variables that operate at large scales are depicted at the top of the tree (for example, broad climatic patterns), while more local effects determine the local variations in distribution. The $\mathbf{R^2}$ value gives an indication of the strength of the regression tree model. As $\mathbf{R^2}$ values approach 1.00, the model becomes more robust at predicting importance values for the species.



Map Page

(See pages 9-10 for further explanation)

The gray shaded portions of the maps (No Data on legends) had no forest information available, due to one or more of the following: (1) there were no data recorded for any tree species for those counties (for example, the prairie states in the western part of the region), (2) one or more of the four FIA regions (northeastern, north central, southeast, southern) did not report the species in their data base because it was not present in the region (for example, distinctly northern or southern species), and (3) one or more of the FIA regions do not recognize a particular species name as present in the unit, even though it undoubtedly is present but called something else (for example, taxonomic confusion such as that in the hickories (*Carya* spp.)).

G. *Current FIA*—This map shows actual recorded distributions (importance values), by county, according to the FIA data. Range boundaries according to maps published by Little (1971, 1977) are also presented in bold for comparison.

H. *Modeled Current*–This is a map of current distribution, as modeled from the RTA, using the tree diagram on the facing page.

I. *Geographic Predictors*–As mentioned in the "Tree Diagram" section on the facing page, this map is tied to the tree diagram, and shows the main variables that drive the distribution of the species. Follow the branches of the tree diagram to the class number at the bottom of each node to match the legend for this map. This output shows a main advantage of the RTA approach, as it shows how different variables can drive the IV of a species at different parts in its range.

J. *Predicted GISS*–This is a map of predicted potential future species distribution, using the GISS global change model scenario (one of many scenarios) and the tree diagram on the facing page. These maps indicate the sensitivity of the species to its current environment and also show which species might require more migration to persist in a globally changed climate.

K. *Potential Shifts*–This map shows the area where the species is currently but not projected to be present in the future (current), where it is not currently present but is predicted to be in the future (predicted), and where it is both currently and potentially in the future (overlap).

L. *GISS Difference*–A map of the difference between Modeled Current and Predicted GISS maps. The scores indicate the changes predicted in IV.

Headquarters of the Northeastern Research Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

Burlington, Vermont, in cooperation with the University of Vermont

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Durham, New Hampshire, in cooperation with the University of New Hampshire

Hamden, Connecticut, in cooperation with Yale University

Morgantown, West Virginia, in cooperation with West Virginia University

Parsons, West Virginia

Princeton, West Virginia

Syracuse, New York, in cooperation with the State University of New York, College of Environmental Sciences and Forestry at Syracuse University

Warren, Pennsylvania

Iverson, Louis R.; Prasad, Anantha M.; Hale, Betsy J.; Sutherland, Elaine K. 1999. **An atlas of current and potential future distributions of common trees of the Eastern United States**. Gen. Tech. Rep. NE-265. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 245 p.

This atlas documents the current and possible future distribution, provides detailed information on environmental characteristics defining the distribution, provides detailed information on the life history characteristics, and provides summary statistics of 80 common tree species in the Eastern United States. Intended to supplement other publications on forest tree species, much of the data provided here are derived from Forest Inventory and Analysis (FIA) data, analyzed in concert with 33 environmental variables within a geographic information system. Life history information, including detailed regeneration and disturbance characteristics, were generated via the literature and are provided in data base format. Summary statistics give overall perspective on the tree species of the Eastern United States. Regression tree analysis models were constructed to determine possible future habitat for each species under two scenarios of global climate change.

URL: *www.fs.fed.us/ne/delaware/atlas*

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