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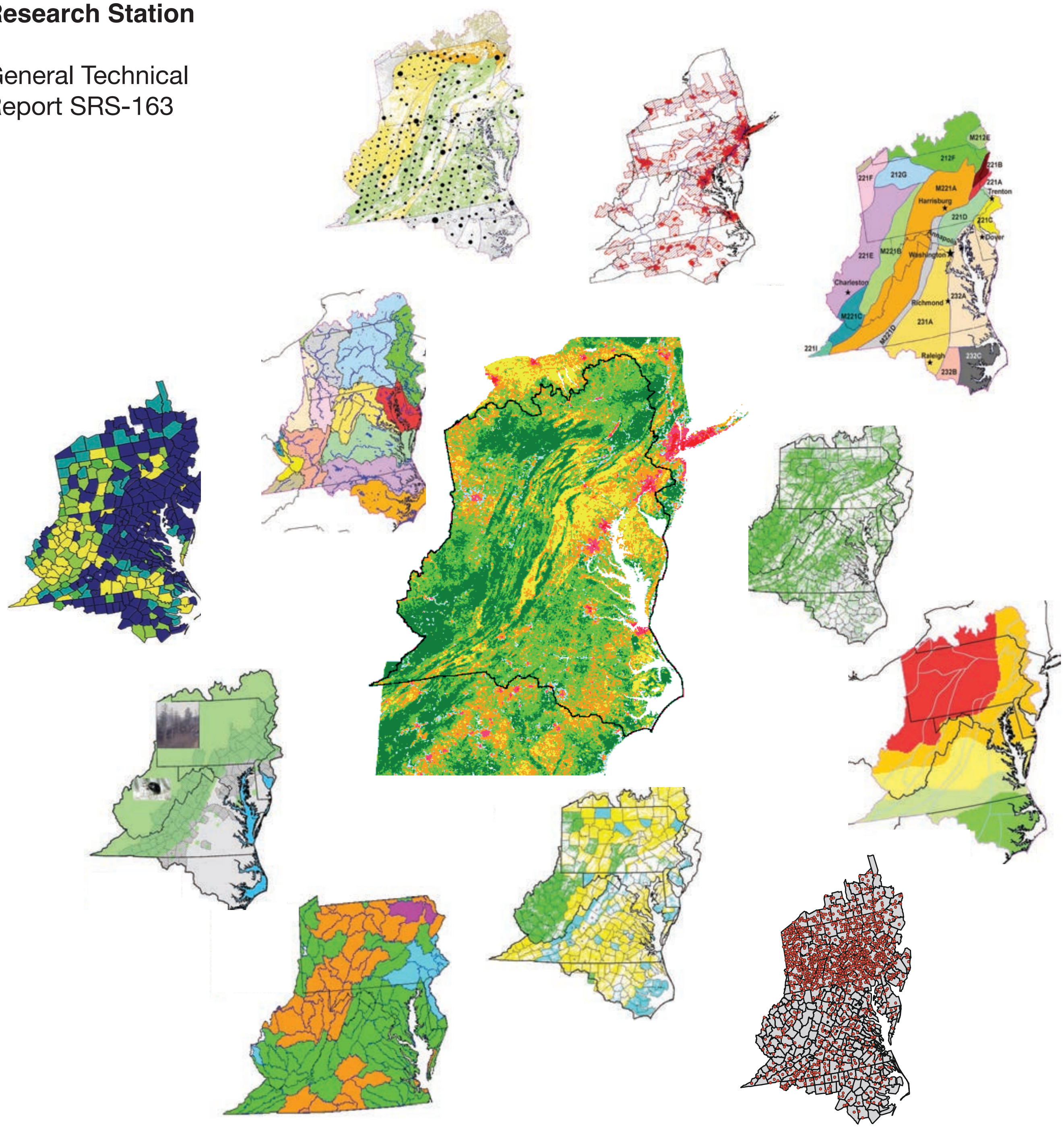
# State of Mid-Atlantic Region Forests in 2000
## Summary Report

**Kenneth W. Stolte**



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Kenneth W. Stolte

INTRODUCTION

# Summary Report

Evaluation of the health of forests in the MAIA region was initiated by the U.S. Environmental Protection Agency's (EPA) Region 3 (Office of Research and Development) and the United States Department of Agriculture Forest Service's (FS) Forest Health Monitoring (FHM) program in the late 1990s. Collection and analyses of ecological, social, and economic data to evaluate the health and sustainability of forests in the Chesapeake Bay watershed was coordinated among the FS FHM Program's National Office (Research Triangle Park, NC), FHM's Regional Office in the Northeastern Research Station (Newtown Square, PA), and FHM's Regional Office in the Southern Research Station (Asheville, NC). Two stakeholder meetings were held in Annapolis Maryland that were instrumental in deciding the content of this report. After two reviews and revisions based on stakeholder input and comments, the stakeholders' list of information needs for the report was finalized and ranked in order of importance to the stakeholders (table 1). A few issues were added by EPA to the report based on post-workshops reviews on the content.

The Mid-Atlantic Integrated Assessment (MAIA) region includes all of Virginia, West Virginia, Maryland, Delaware, Pennsylvania, and parts of New Jersey, southeastern New York, and northeastern North Carolina (fig. 1). The boundary for the MAIA region is based primarily on watershed landforms, management units, etc. The MAIA region is a large area covering about 103,211,100 acres of land.

Analyses and interpretation of much of the data is based on Bailey's ecoregion sections because the response of forest ecosystems to stress is significantly affected by the underlying climatic, geological, and topographic features of the system, and ecoregions are based on those factors. Because many ecoregion sections extend well beyond the northern and southern borders of the MAIA region, only portions of ecoregion sections in the MAIA region were considered in most of the analyses.

The MAIA region comprises a wide variety of forest communities, each of which is home to numerous plant and animal species. The Region contains all or portions of nineteen ecoregion sections, from the eastern coastal plains to the western mountains (fig. 2).

It also contains all or portions of seventeen watersheds (fig. 3). The eastern half of the MAIA region drains into the Atlantic Ocean. It is bounded by the Delaware Bay watershed to the north and the Pamlico Sound watershed to the south. In the western portion, the Allegheny and

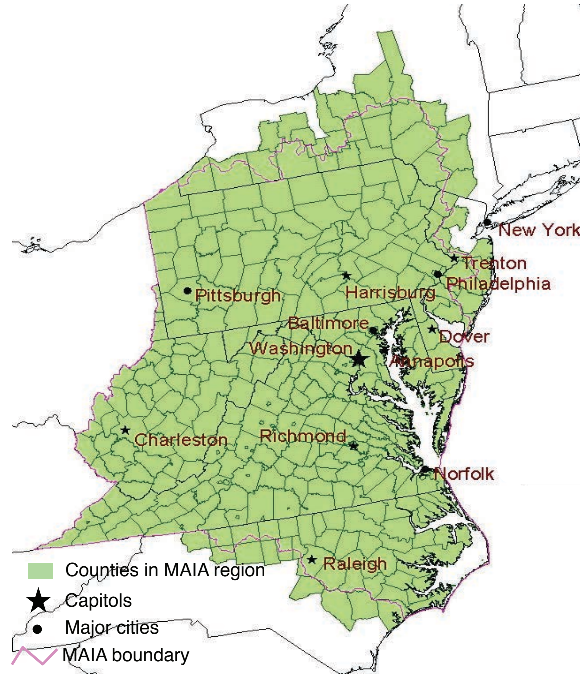


Figure 1—The Mid-Atlantic Integrated Assessment (MAIA) region includes all of Maryland, Virginia, West Virginia, Pennsylvania, Delaware, District of Columbia, and whole or partial counties in northeast North Carolina (~47), western New Jersey (~12), and southeastern New York (~25).
Source: Chapter 2, Figure 1.

Monongahela watersheds, as well as most of the Kanawha River watershed, are entirely within the region's boundary. The MAIA region also includes about two-thirds of Big Sandy-Guyandotte, one-fourth of Tennessee River, and one-half of Upper Ohio River watersheds.

The report on the condition of forests in the MAIA region focused on facets of biological diversity, productivity, vitality, soil and water, and carbon; the same factors that comprise the five ecological criteria of the Montreal Process Criteria and Indicators. The primary issues included in the report are:

- type and extent of forest, land-use, urbanization, and fragmentation;
- forest products and economics;
- urban forest condition and street trees;
- native plant species, non-game wildlife, forest birds, and habitats;
- gaseous and particulate air pollution;
- endemic insects and diseases;
- altered fire regimes;

**Table 1—Rank of forest health stressors, response, and condition topics from two MAIA Stakeholder Workshops in Annapolis, Maryland in 1997 (Source: Chapter 2, Table 1)**

| Category | Component | Assessment issue[a] | Stakeholder priority[b] |
|---|---|---|---|
| Stressors | Abiotic | *Air pollution* | 10.0 |
| | | Storms (hurricanes, ice) | 6.3 |
| | | Fire (lightning strikes) | 6.3 |
| | Biotic | *Insects and diseases* | 9.5 |
| | | Animal damage | |
| | | *Exotic plants* and animals | 8.3 |
| | Land use | *Urban expansion* | |
| | | Fire[e] and *fire suppression* | 6.3 |
| | | Mining activities | |
| | | *Timber harvest* | 7.6 |
| | | *Road building* | 6.3 |
| Response[c] | Tree vitality | *Crown dieback* | 5.9 |
| | | *Tree damage* | 6.3 |
| | | *Tree mortality* | 8.5 |
| | | *Tree regeneration* | 10.0 |
| Condition[d] | Productivity | *Timber productivity* | 7.6 |
| | | Non-timber productivity | 5.0 |
| | | *Game species productivity* | 7.5 |
| | Soils systems | Erosion | 8.3 |
| | | Accumulation of toxins | 8.8 |
| | | *Nutrient pools and cycling* | 8.3 |
| | | Compaction | 5.5 |
| | Aquatic systems | *Sedimentation* | 10.0 |
| | | *Chemical Contamination* | 10.0 |
| | | Riparian buffers | |
| | Carbon sequestration | *Soil carbon* | 8.3 |
| | | *Above-ground trees* | |
| | | Above-ground plants | |
| | Biological diversity | *Plant species richness* | 7.5 |
| | | Non-game wildlife species richness | 9.0 |
| | | *Forest birds species richness* | 9.0 |
| | | Habitat suitability for T & E species | 9.0 |

[a] Issues in italics were addressed in MAIA report.
[b] Based on average of low(3), medium (6), and high (10) ratings.
[c] Addressed Criterion 3 of Montreal Process Criteria and Indicators (Anon. 1995b).
[d] Addressed Criteria 1, 2, 4, and 5 of Montreal Process Criteria and Indicators (Anon. 1995b).
[e] Human-caused ignitions.

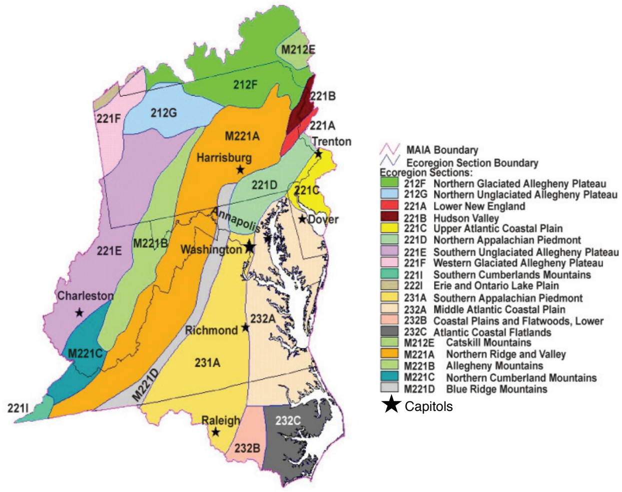


Figure 2—Bailey's ecoregion sections within the MAIA region. The U.S. Forest Service's Forest Health Monitoring, Forest Inventory and Analyses, and other programs data were frequently averaged at these spatial scales for comparison of forests within the MAIA region. Source: Chapter 3, Figure 5.

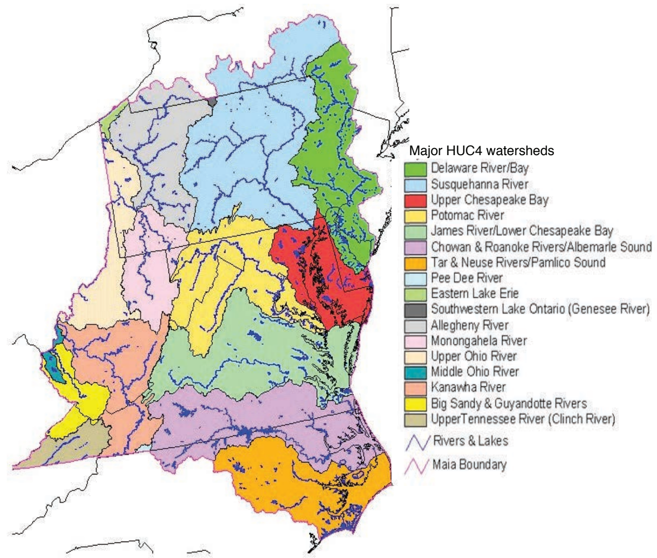


Figure 3—Major 4-Digit Hydrologic Unit Code (HUC4) watersheds in the MAIA region. Some data from the U.S. Forest Service's Forest Health Monitoring program was averaged at HUC4 spatial scales to assess differences with ecoregion section values and provide potential for comparisons with water condition.
Source: Chapter 3, Figure 6.

- exotic plants, insects, and diseases;
- tree condition, growth, mortality, and regeneration;
- aquatic sedimentation, chemical contamination, and landuse effects;
- soil erosion, nutrient pools and cycling, and soil carbon;
- climate change

This report addresses many of the most relevant issues concerning forest health and sustainability. The report was generally organized by historical perspectives; resource base in 2000; stressors affecting the region today; tree-level indicators affected by stressors; and the overall condition of the MAIA forest today with respect to productivity, soil and aquatic systems, and biological diversity.

## History of MAIA Forests

The forests of the MAIA region today are a remnant of what existed only 400 years ago, yet this remnant is still an impressive organization of plants and animals, magnificent vistas, and bountiful aquatic systems. Prior to colonization (circa 1650), the entire mid-Atlantic region was a near-continuous blanket of forest composed of multiple tree species of different ages, sizes, and abundances that covered over 95 percent of the land surface, or approximately 100 million acres.

The early forests were predominately composed of oaks, chestnuts, pines, hemlock, beech, maple, birch, ash, black cherry, sweet gum, magnolia, and hickory, with spruce and fir at higher elevations, and swamp tupelo and bald cypress found on wetter coastal sites. The air, streams, estuaries, and bays were clear and unpolluted, abounding in a great diversity of aquatic plants, insects, animals, and aquatic life. The soils were very deep and rich, derived from millions of years of erosion of Appalachian and other mountain systems that run from north-to-south. The climate was mild and moist, and combined with the topographical diversity of the area, nurtured a great diversity of plants, animals, and aquatic systems that had coevolved and flourished in a balanced, healthy, and sustainable system.

Early colonization was followed by rapid population growth and urban and agricultural expansion in the 17th and 18th centuries. The area of forests remained relatively stable until the period 1740 to 1930, when 80 percent of the lands covered with forests were cleared for agricultural purposes. By the early 1900s, tens of millions of acres of forest had been cut for farmland, fuel, fences, railroad ties, and other products. For the first time in thousands of years much of the contiguous forest area of MAIA region were almost completely laid barren. Catastrophic fires that started from burning residual slash and other activities burned millions of acres of forest not cleared, and subsequent excessive soil erosion erased many millennia of rich soil development. Sedimentation of streams and rivers from forest clearing and agricultural runoff, a concern in the MAIA region since the mid-1750s, became greatly exacerbated. Whole towns were buried in mud when heavy rains washed the exposed soil from the steep slopes. Many wildlife species—including the now common whitetail deer, turkey, and black bear—were almost extinct.

## Forests in the MAIA Region Today

Restoration of MAIA region forests started in early 1900s. The area of forestland increased as advances in agricultural practices required less land to grow more crops, and improved timber harvest methods were implemented. Forest ecosystems improved: wildlife was protected; soil erosion and infertility was mitigated by allowing relatively infertile farm land to return to forests; and catastrophic wildfires followed by devastating flooding were reduced by better forest management practices. Though much improved today, the forests are still in recovery from the intensive agricultural and removal of tree products of the 1700s and 1800s.

Today 63,651,000 acres (about 61 percent) is classified as forestland (both federal and non-federal land), and 39,560,100 acres (about 39 percent) is classified as non-forestland. Federal forestlands cover only 3,626,200 acres, about 3.5 percent, of the MAIA region. Private land owners control 79 percent of the MAIA forests, public land managers 14 percent, and forest industry 7 percent.

Ninety-five percent of forestland today is classified as productive timberland (table 2), with more than half (54 percent) considered harvestable from a timber industry perspective (many trees in a stand greater than 10 inches in diameter).

Yet the forests are still very immature from an ecological perspective because much of the forest has been re-colonizing abandoned, infertile farmlands since the early 1900s—soils are still redeveloping organic matter and nutrients, and most tree species have not reached 50 percent of their maximum age and thus are not fully matured. There is an obvious absence of old growth trees (large and mature) that were common in pre-European times—less than 2 percent of the trees today are greater than 20 inches in diameter. About 72 percent of trees are saplings (trees less than 5 inches in diameter), and 16 percent are in a seedling or regenerative phase (less than 1 inch in diameter and greater than 10 inches high).

Most of the forests in the MAIA region today are owned by private landowners (79 percent), industry (7 percent), Federal (6 percent), State (7 percent), and municipal and county governments (1 percent): the future of these

**Table 2—Land cover types in MAIA states circa 2000 (Source: Chapter 2, Table 2)**

| States | Woodland | Reserved | Total forest[a] | Non-Forest | Total land[b] | Forest | Non-forest |
|---|---|---|---|---|---|---|---|
| | *thousand acres* | | | | | *percent* | |
| Delaware | 10.2 | 2.0 | 388.2 | 847.2 | 1,235.2 | 31.4 | 68.6 |
| Maryland | 126.4 | 152.9 | 2,703.4 | 3,592.2 | 6,295.4 | 42.9 | 57.1 |
| New Jersey[c] | 5.6 | 86.2 | 1,717.6 | 2,040.5 | 3,758.6 | 45.7 | 54.3 |
| New York[d] | 47.9 | 799.9 | 8,425.0 | 5,729.1 | 14,154.9 | 59.5 | 40.5 |
| North Carolina[e] | 321.0 | 87.0 | 8,386.0 | 6,475.0 | 14,861.0 | 56.4 | 43.6 |
| Pennsylvania | 285.0 | 834.9 | 16,992.9 | 11,735.6 | 28,728.5 | 59.2 | 40.8 |
| Virginia | 47.0 | 532.0 | 16,026.0 | 9,382.0 | 25,408.0 | 63.1 | 36.9 |
| West Virginia | 27.7 | 181.1 | 12,126.8 | 3,309.5 | 15,436.3 | 78.6 | 21.4 |
| MAIA total | 581.8 | 2,676.9 | 66,766.9 | 43,111.1 | 109,877.0 | 60.7 | 39.3 |

[a]Total forest = woodland + reserved + timberland.
[b]Total land = total forest + non-forest.
[c]Includes all or part of 12 counties only.
[d]ncludes all or part of 25 counties only.
[e]Includes all or part of 47 counties only.
Source: USDA Forest Service's Forest Inventory and Analysis Program; (http://www.fia.fs.fed.us).

forests lies in the decisions made by these various entities. Urban and surrounding metropolitan forests are significant component of the MAIA region (table 3).

Average percentage of total area in all MAIA states was 10.3 percent in urban areas and 49.7 percent in metropolitan areas (MA) (fig. 4), compared to an average 3.5 percent in urban area and 24.5 percent in metropolitan area for the U.S. (excluding Alaska and Hawaii). With the exception of West Virginia, metropolitan areas accounted for more than 34 percent of all MAIA states.

The benefits and values of urban forests include esthetics, biodiversity, flood control, water preservation during droughts, refilling aquifers, water quality maintenance, temperature and climate control, energy conservation, and recreational activities such as bird watching and hiking. Some common stressors affecting urban trees are pollution, soil compaction, nutrient deficiencies, drainage problems, salt uptake, construction damage, insects, and pathogens.

Forests in the MAIA region provide important recreational opportunities, wildlife habitat, aesthetic benefits, timber

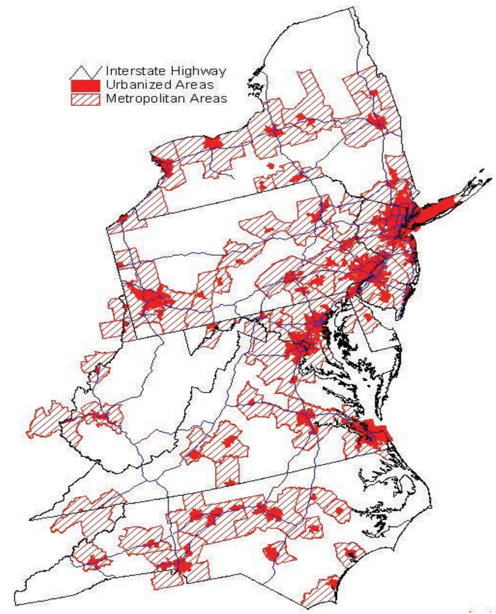


Figure 4—Metropolitan and urban areas in the MAIA region. Source: Chapter 4, Figure 8.

**Table 3—Tree cover in metropolitan areas (MA) and urban areas (UA) by State area and tree cover in MAIA region and the U.S. circa 2000 (Source: Chapter 5, Table 6)**

| State | Total Area[a] | Area | | State[b] | | Tree Population | | Tree Cover[c] | | State Tree Cover[d] | | Trees per Capita | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MA | UA | MA | UA | MA | UA | MA | UA | MA | UA | MA | UA |
| | *thousand acres* | | | *percent* | | *million* | | *percent* | | *percent* | | | |
| DE | 1,590,192 | 828 | 140 | 52.0 | 8.8 | 213 | 13 | 50.9 | 46.3 | 58.2 | 9.0 | 384 | 27 |
| MD | 7,930,094 | 4,530 | 1,118 | 57.1 | 14.1 | 851 | 89 | 46.5 | 40.1 | 53.2 | 11.1 | 192 | 21 |
| NJ[e] | 5,579,730 | 5,580 | 1,708 | 100.0 | 30.6 | 1,597 | 144 | 56.6 | 41.4 | 100.0 | 22.3 | 207 | 20 |
| NC[e] | 34,455,837 | 11,987 | 1,586 | 34.8 | 4.6 | 4,357 | 139 | 52.5 | 42.9 | 31.4 | 3.4 | 996 | 36 |
| NY[e] | 34,804,462 | 17,992 | 2,501 | 51.6 | 7.2 | 4,598 | 133 | 44.7 | 26.3 | 43.9 | 3.5 | 278 | 8 |
| PA | 29,482,538 | 14,404 | 2,066 | 48.9 | 7.0 | 3,733 | 139 | 48.7 | 34.4 | 43.5 | 4.2 | 370 | 16 |
| VA | 27,370,151 | 10,068 | 2,191 | 36.8 | 8.0 | 3,648 | 157 | 53.3 | 35.3 | 34.4 | 4.9 | 764 | 27 |
| WV | 15,643,123 | 2,497 | 268 | 16.1 | 1.7 | 891 | 23 | 65.6 | 42.2 | 13.4 | 0.9 | 1,191 | 33 |
| U.S.[f] | 991,628,365 | 488,986 | 69,407 | 24.5 | 3.5 | 74,426 | 3,821 | 33.4 | 27.1 | 24.5 | 2.8 | 377 | 17 |

[a]Includes land and water area combined.
[b]Percent of total State area covered by metropolitan areas (MA) and urban areas (UA).
[c]Percentage of metropolitan and urban areas covered by trees.
[d]Percentage of total state tree cover within metropolitan areas and urban areas.
[e]Includes entire State, not just counties in MAIA region.
[f]Includes District of Columbia, but not Alaska and Hawaii.
Source: Dwyer and others 2000.

products, clean and abundant fresh water, and aquatic habitat for a variety of species. The remaining forests contain a rich diversity of forest types and species. Some forest stands, particularly in the northwestern portion of the region, are in the process of returning to the magnificent older-growth forests reminiscent of the pre-colonization era.

The significant progress in improving and maintaining forest ecosystem health and sustainability over the past century is balanced against increasing human demands for good and services. The forests face a variety of new and old threats from diverse biotic and abiotic stressors, including:

- continued conversion and/or fragmentation of forests by urban expansion
- introduction of exotic and invasive insects, pathogens, plants, and animals
- gaseous, particulate, and acidifying air pollution
- alteration of historical fire regimes
- extraction of timber and other resources
- climate change

These forest health issues are a great concern to the public, and to the land managers and policy makers who are responsible for maintaining long-term vitality of the forests in the MAIA region.

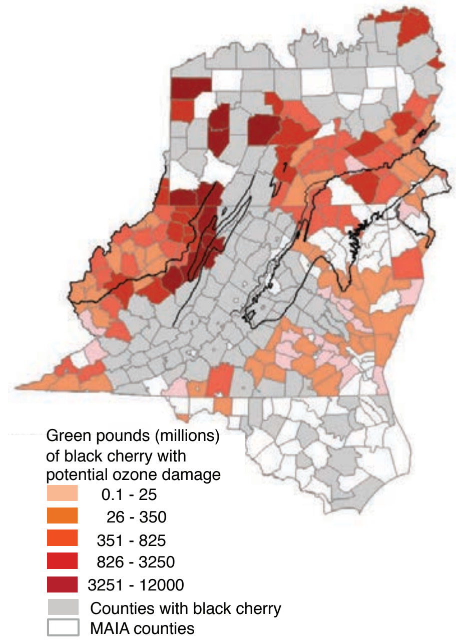


Figure 5—Potential biomass loss in black cherry in 1990 where the distribution of this species overlapped areas with phytotoxic ozone exposures in the MAIA region.
Source: Chapter 6, Figure 17.

## STRESSORS AFFECTING THE MAIA FORESTS

*Air Pollution*

Air pollution is a relatively new force affecting MAIA forests. Relatively high exposures of gaseous ozone, and deposition of ions such as nitrates, sulfates, and acidic precipitation have the potential to decrease growth, increase susceptibility to other stressors, increase mortality, and alter the structure and function of forest communities.

Ground-level ozone degrades susceptible plant species (ozone bioindicator species) when it enters the foliage during normal gas exchange processes and kills the carbon-fixing cells that provide food and energy for plants and animals. Ozone exposures were sufficiently elevated to injure a number of ozone bioindicator species (trees, shrubs, and herbs species) throughout the MAIA region from 1993 through 1996. Ozone effects on bioindicator species was often the highest Level 3 injury in the north and western parts of the MAIA region. The negative effects of ozone air pollution are evident by the potential biomass losses of 3,250 to 12,000 green pounds for black cherry in the western sections of the Region in 1990 (fig. 5).

Deposition of sulfates, nitrates, and hydrogen ions (pH) degrade forest ecosystems by increasing soil acidity and removing important plant nutrients, and subsequently contaminate aquatic systems. Average wet deposition of sulfate for the period from 1979 to 1995 ranged from a low of 17.5 to 21.3 kilograms per hectare per year (kg/ha/yr) in the southeast regions of MAIA, to the highest levels of 32.8 to 36.6 kg/ha/yr in the northwest regions. Similarly, average wet nitrate deposition for the same period ranged from 10.2 to 12.4 kg/ha/yr in the southeast region to the highest levels of 18.9 to 21.1 kg/ha/yr in the northwest region. The annual average pH of the precipitation for this same period ranged from 4.49 to 4.57 in the southeast region and 4.18 to 4.26 in the northwest part of the MAIA region (fig. 6).

The northwest portions of the MAIA region were subjected to some of the highest ozone exposures and wet deposition of air pollutants in the eastern U.S. The effects of these pollutants on the forest resources of the MAIA region are not known at this time. Additional analysis is needed of the relationship between air pollutants and forest growth, understory diversity, soil chemistry, crown condition, lichen communities, and ozone-susceptible species.

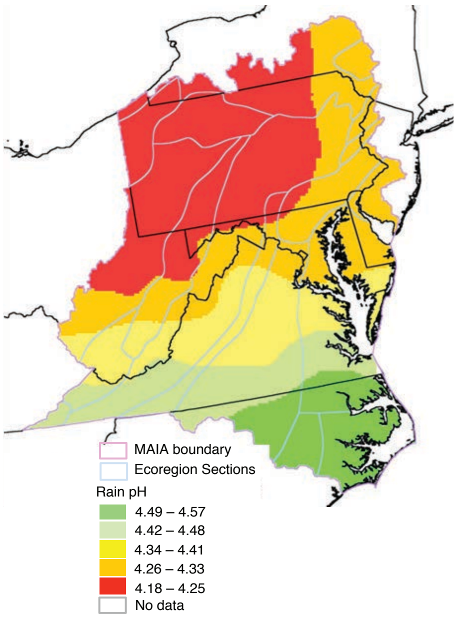


Figure 6— Average annual precipitation pH in the MAIA region from 1979 to 1995. Data from this 16-year period were averaged and interpolated at 5-km grid scale to estimate average annual wet deposition at ecoregion section scales.
Source: Chapter 6, Figure 20.

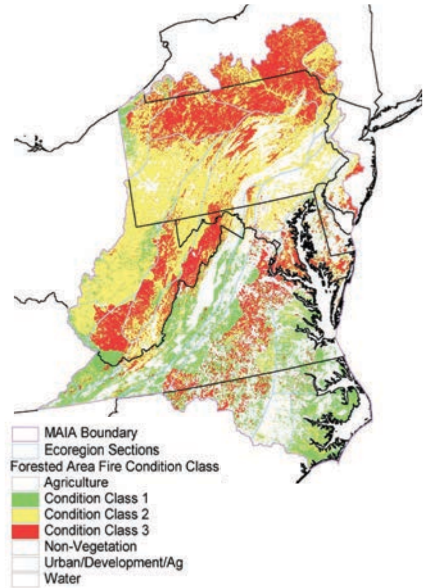


Figure 7—Condition classes of changes in current fire regimes from historic fire regimes in forested areas in the MAIA region. Higher numbered condition classes indicate increasing amounts of silvicultural treatments would be needed to restore historic fire regimes.
Source: Chapter 7, Figure 22.

*Alteration of Fire Regimes*

Almost all forests eventually catch fire and burn: fire is a natural part of almost all healthy and sustainable forest ecosystems. Fires cycles or regimes have historically differed according to regional climate, soils, topography, and other factors. Fires regimes are basically the average of how often fires burn and how severe the fires are—frequent fires are typically low intensity fires, and severity of impacts are limited because only low amounts of fire fuels accumulated in the fire intervals. Frequent, low intensity cycles are typically ground fires that burn the understory vegetation without much impact on the boles or crowns of the larger overstory tree species.

Fire regimes in the U.S. range from relatively frequently (about every 3 decades) with low intensity and severity, to long-term, infrequent fires (35 to 100 to 200 years or longer) with greater intensity and severity. Forests can only stay healthy and in natural conditions if the fire regimes they adapted to over thousands of years continue to operate, or if some other agent or management activity substitutes for the effects of a normal fire regime. Historic fire regimes in most of the southern forests in the MAIA region burned frequently (0 to 35 years) with low severity. In the northern MAIA, fire burned less frequently (35 to 100+ year cycles) and with low-to-mixed severity.

Forest fire-suppression management activities have altered the historic fire regimes in the MAIA region and created the need for moderate-to-intensive silvicultural activities to restore these forests to historic ecological conditions. The alteration of fire regimes often facilitates insect and pathogen epidemics, and increases the risk of more severe crown fires during periods of prolonged drought. The greatest deviations from historical fire regimes are in the northern and western portions of the MAIA region and in scattered fragments within the Piedmont area in the southeast (fig. 7).

*Climate Change*

Climate is generally the long-term variability of temperature and moisture that changes as the earth circles the sun. It is unquestionably the most significant factor affecting the composition, structure, and functioning of forest and other ecosystems. Climate distributed across landscapes of varying soil types and topography is the primary basis for the categorization of ecoregion units and the forest types and species found there. Thus changes in climate regimes can be expected to greatly affect forest ecosystems.

Forests in the MAIA region have changed significantly over millennia as the result of changing climate regimes. Monitoring, models, evidence from tree rings and sediment

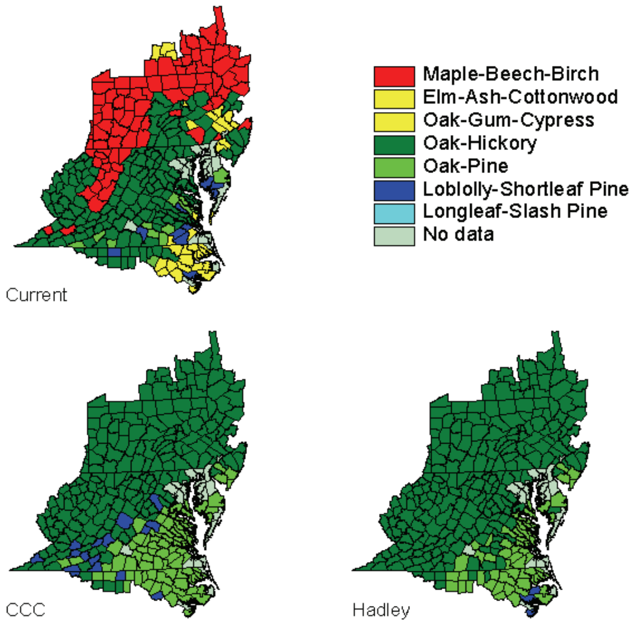


Figure 8—Dominant forest types under circa 2000 climate regimes, and potential forest type distributions under Canadian Climate Center and Hadley doubled $CO_2$ equilibrium climate scenarios. Source: Chapter 8, Figure 23.

cores, and other factors generally indicate that a period of significant climate change is in progress today that is expected to significantly affect forest ecosystems. In the MAIA region, temperature increases of 4 to 8º F, decreases in the amount of precipitation, and increases in the intensity of storms are anticipated by the end of the 21st century. A few models, however, predict increases rather than decreases in precipitation. Generally the expected changes in climate are anticipated to increase growth of forests but also change the composition of tree species. Major forest types like maple-beech-birch and oak-gum-cypress are likely to be negatively affected with significant reductions in coverage (fig. 8).

Changes in dominant forest types are likely to increase invasions of exotic species and decrease biological diversity. It is also likely that negative effects on cold water fish (e.g., trout) and some bird species will occur. Forest operations are likely to be more negatively affected by increases in severe weather (high winds and precipitation events) than by increases in temperature.

*Insects and Pathogens*

Native insects and pathogens have coevolved with forest ecosystems and are an essential part of normal, healthy forests, but they are also always a concern because significant changes in forest or environmental conditions—e.g., fire suppression, timber harvest activities, climate change, prolonged drought, and other factors—can cause native insects and pathogens to become abnormally prolific and populations can reach epidemic proportions with devastating results. Alternately exotic and highly invasive insects and pathogens are almost always a serious threat to forest ecosystems because they lack the inherent regulatory mechanisms that control populations in their native lands. They often cause severe devastation and can even threaten the existence of important tree species. For example, chestnut blight is an introduced pathogenic fungus that has devastated the eastern U.S. forests over the last 100 years, virtually eliminating the once abundant and magnificent American chestnut by the 1950's. American chestnut was once the most dominant hardwood tree in the vast stands of Eastern forests from Maine to Florida.

Some tree species in the Mid-Atlantic are at extreme risk from exotic insects and pathogens, with projections of 25 percent or more increases in mortality over the next 15 years. The most serious insects and pathogens in the MAIA region include gypsy moth (fig. 9), hemlock woolly adelgid, butternut canker, beech bark disease, and dogwood anthracnose. Some pests such as gypsy moth are generalists,

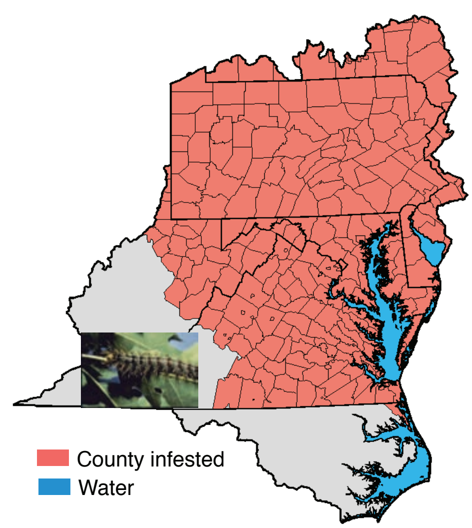


Figure 9—Gypsy moth infested areas in MAIA counties through 1998 with gypsy moth caterpillar photograph (inset). Source: Chapter 9, Figure 24.

attacking a variety of tree species, while others like hemlock woolly adelgid and dogwood anthracnose are host-specific, as their common names imply.

There is a high probability that some tree species such as butternut and hemlock may be lost entirely from MAIA forests, with serious ramifications for the stability of the forest systems they occupy. For example, hemlocks in the MAIA region are often found along stream banks where they stabilize the soil, provide wildlife habitat, and moderate water temperatures. The loss of this tree species in large numbers will greatly degrade the associated aquatic systems. In other areas insects and pathogens will severely degrade, but not eliminate, the host species and will consequently alter the composition, structure, and function of forests in the affected areas.

*Exotic Plant Species*

Exotic plant species that are highly invasive are becoming a significant part of the flora in the forests of the MAIA region. Exotic plant species are also very successful when invading native plant communities because of the absence of the natural biotic and abiotic agents that keep them in check in their native habitats. In the MAIA region, exotic plants—mostly occurring in the understory—comprised 20.6 to 34.7 percent of the total flora in some counties, particularly around major urban centers or highways. Queen Anne's lace or wild carrot was the most common exotic plant species found in 93 percent of the counties evaluated, followed by red clover (91 percent of counties), and narrowleaf plaintain (90 percent of counties). Seven other exotic species were found in 80 percent or more of the MAIA counties (table 4).

The effect of these exotic plants on native plant communities in the MAIA region is largely unknown at this time, but exotic plant species typically displace a disproportionate number of native species and thus significantly reduce plant biodiversity, and subsequently often affect animal species by eliminating native plant species essential for food, nesting, or shelter.

*Population Growth and Urbanization*

Rapid expansion of populations and concurrent urban development fragments forest ecosystems, negatively affects forest health, and causes serious problems for natural resource managers, urban planners, and policy makers. Urban expansion increases the risk of wildfires, disrupts animal habitat and populations, introduces exotic invasive species, and often degrades water quality. It creates unique situations where the need to protect water quality, wildlife, and forest health must be balanced with the social, recreational, health, and safety needs of people.

**Table 4—Exotic plant species in MAIA region States circa 2000 (Source: Chapter 10, Table 10)**

| Rank | Common name | Occurrence in MAIA counties |
|---|---|---|
| | | -----percent----- |
| 1 | Queen Anne's lace | 93 |
| 2 | *Red clover* | 91 |
| 3 | *Narrowleaf plaintain* | 90 |
| 4 | Ox-eye daisy | 88 |
| 5 | *Sheep sorrel* | 88 |
| 6 | Barnyard grass | 88 |
| 7 | *White clover* | 84 |
| 8 | *Yellow sweet clover* | 84 |
| 9 | *Woolly mullein* | 81 |
| 10 | *Asiatic day flower* | 80 |

Note: County-level records for Maryland, and the western counties of Pennsylvania and New York, were not obtained. Source: The Biota of North America Program; (http://www.bonap.org).

Between 1970 and 1990 the population of the MAIA region increased by 4.3 million people (14.1 percent) to about 35 million people in the 171,129 square miles of the MAIA region, and the average population density increased from 179 to 204 people per square mile (psm). Nevertheless, population density was lower in 1990 than in 1950 in many parts of the region, indicating that most of the population increases were in the already urbanized areas and came from rural areas. Developed lands increased by 21 percent, while rural lands decreased by 2.64 percent from 1982 to 1994, indicating that agricultural lands were converted to urban development. North Carolina, Delaware, Maryland, New Jersey, and Virginia all lost forest land to urbanization, while New York and West Virginia showed increases in forest land over the same period. Forests still dominated the MAIA landscape, making up 61 percent of the land area.

The average population density by State ranged from 75 psm in West Virginia to 608 psm in New Jersey. At the county level population density ranged from 6 to 45 psm in western regions to 2001 to 15000 psm in the eastern regions (fig. 10.a). Delaware and Maryland increased by 21 percent, and Virginia by 30 percent (fig. 10.b.).

The highest population densities were concentrated in the Erie/Ontario Lake Hills and Plain region, along Interstate 95 corridor from Philadelphia, PA to Chesapeake, VA. Some

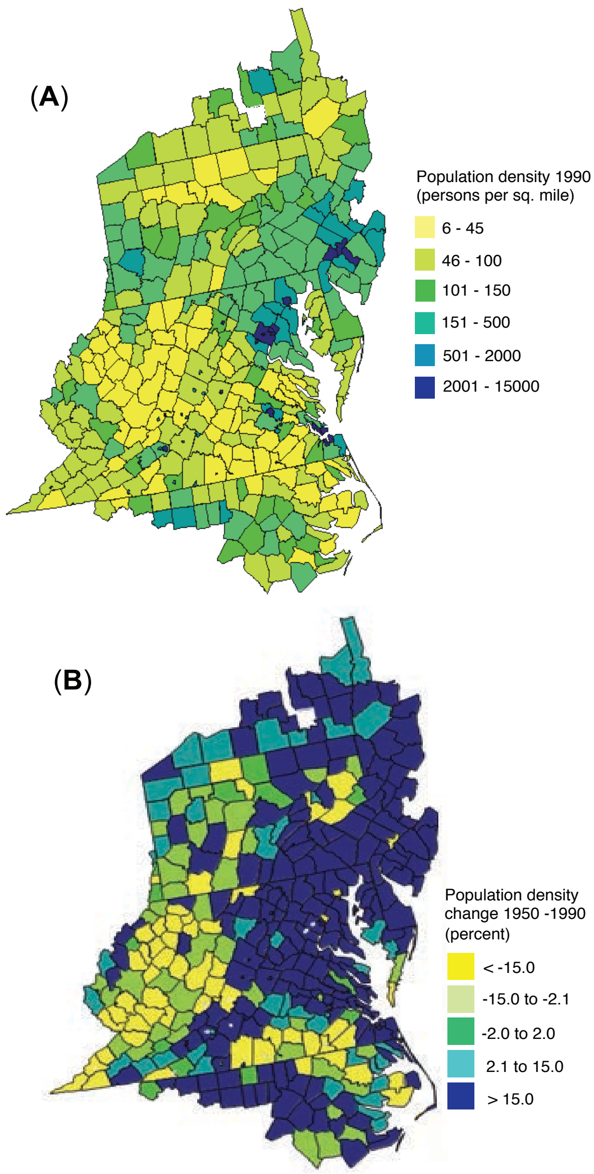


Figure 10—(a) Population density in MAIA region in 1990. (b) Change in population density 1970 to 1990.
Source: Chapter 11, Figures 31 and 33.

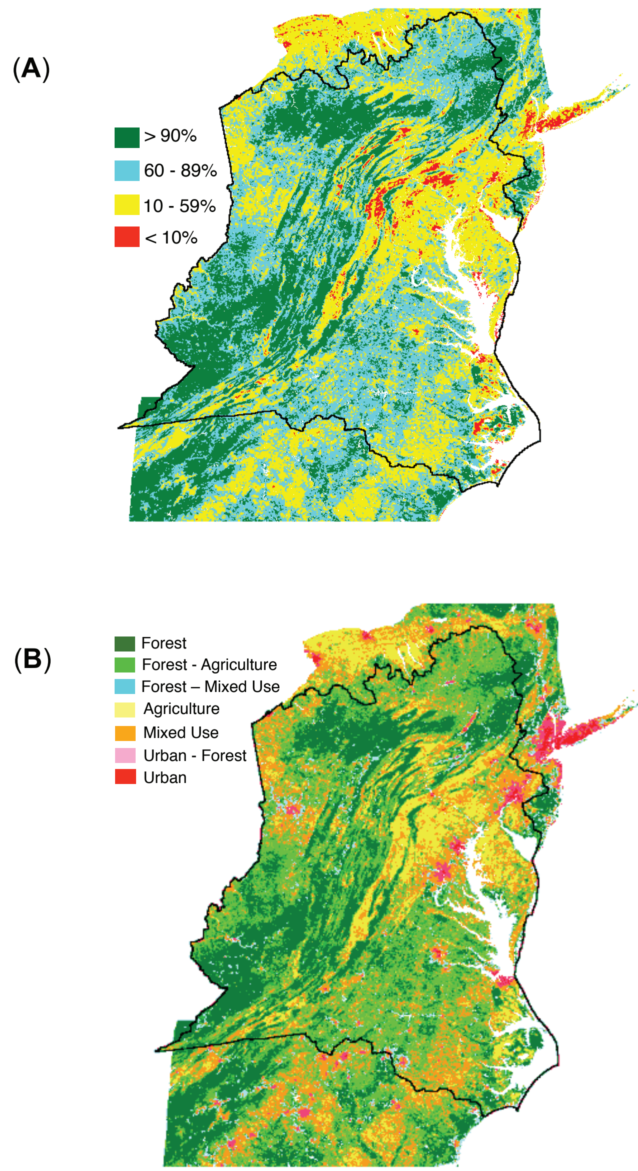


Figure 11—(a) Forest cover within 1457 acre landscape units in the MAIA region circa 1990. The fine-scale (0.22 acres per pixel) land cover map from EPA's MRLC was generalized to show the proportion of forest cover within the 1457 acre units. Areas with more than 90 percent forest cover are highly interior forested landscapes; in contrast to highly fragmented units with less than 10 percent forest cover. A 60 percent cover threshold separates interior forests from more fragmented forests. (b) Type and distribution of Landscape Pattern Types (LPTs) in the MAIA region circa 1990. LPTs are labeled according to the type and relative amount of forest, agriculture, and developed areas within the surrounding 590-hectare units. The 19 MRLC LPT defined categories were condensed into 7 LPT aggregates to simplify regional patterns.
Source: Chapter 4, Figures 12 and 13.

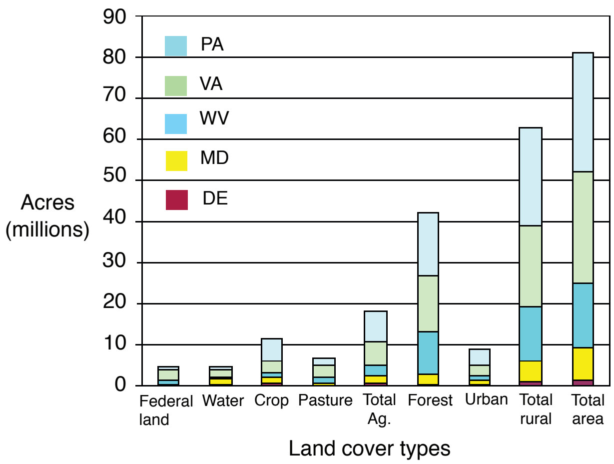


Figure 12— Land cover in five MAIA region states in 1997. Total agriculture is the combination of crop lands and pasture lands. Source: Chapter 11, Figure 37.

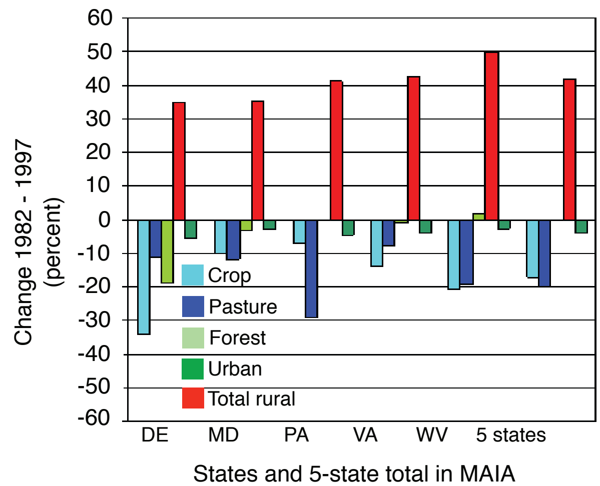


Figure 13— Differences in major land cover types in five MAIA region states 1982 to 1997. Total agriculture (AG1) is the combination of crop and pasture lands.
Reference: Chapter 11, Figure 41.

of the most densely populated urban centers in the East are found in Erie and Philadelphia, PA; Newark, NJ; Baltimore, MD; Washington, DC; and Norfolk-Chesapeake VA. Forest cover in these areas is low and highly fragmented. Thus interactions of forests and humans can be expected to be quite different between the rapidly urbanizing Eastern seaboard and the inland rural areas of the western region.

Increasing human population densities had two important effects on the management of private forest lands and on timber supply. An obvious impact was the conversion of forest land to urban and residential use in areas of high population growth. An increasing number of people owning smaller forestland holdings leads to increasing forest fragmentation in all States of the Region except Pennsylvania, New York, and West Virginia (fig. 11 a.) as changes in landuse occurred (fig. 11 b).

Areas of moderate population density increases were also affected as landowners changed strategies from long-term investments in forest management to expectations of large future returns from converting forest lands to urban and residential use. The transition from rural to urban uses of forest lands occurs between 20 to 70 psm, that is, there is a 75 percent probability of managing forest for timber and similar uses at 20 psm, but only a 25 percent probability of the same at 70 psm. The probability that a forest would be managed for timber-related products approaches zero when populations exceed 150 psm.

*Land Use and Land Use Change*

A relatively small decrease of only 247,100 acres of forestlands compared to a much larger decrease in agricultural lands (crops and pasture) resulted in an overall 1.4 percent increase in forest cover of rural lands from 1982 (62.3 percent) to 1992 (63.7 percent) in the MAIA region. In 1992 this total rural acreage used as cropland decreased by 8.32 percent and pastureland use dropped 8.55 percent, accounting for 20.4 percent and 11.4 percent of the total rural lands, respectively.

Changes in forest, cropland, pasture, urban, Federal ownership, and water bodies land use from 1982 through 1997 were evaluated for Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, the five states located entirely within the MAIA region (fig. 12).

In 1997 these five States covered about 80,993,900 acres, of which 62,909,900 acres were rural lands (77.7 percent) composed of 11,354,000 acres of croplands (14.0 percent), 6,868,400 acres of pasture (8.5 percent), 42,100,000 acres of forests (52.0 percent), and 2,587,500 acres (3.2 percent) of other land uses including minor land (farm structures, wind breaks, other) and Conservation Reserve Program lands. Other land-use types covered 8,943,800 acres of developed (urban) lands (11.04 percent), 4,781,600 acres of Federal ownership (5.90 percent), and 4,517,700 acres of water bodies (5.58 percent).

The percent of urban lands increased substantially in each of the five States during this same period, and crops and/or pasture lands decreased by about the same extent (fig. 13).

Urban lands primarily replaced crop and pasture lands in West Virginia and Pennsylvania, and primarily replaced crop lands in Delaware, Maryland, and Virginia. The percentage increase in urban lands was substantial for Delaware (35.0 percent), Maryland (35.4 percent), Pennsylvania (41.3 percent), Virginia (42.6 percent), and West Virginia (49.6 percent), an average percent increase for all five States of 41.4 percent. The percent change in all agriculture lands (crops and pasture) was highest in Virginia (about 20 percent). Pasturelands decreased by over 25 percent in Delaware and Pennsylvania, and croplands decreased by more then 15 percent in Virginia and West Virginia.

As a result of the increases in urban land use, total rural land area decreased in Delaware by 5.6 percent, Maryland by 3.1 percent; Pennsylvania by 4.7 percent; Virginia by 4.1 percent; and West Virginia by 2.9 percent. The average decrease in total rural lands for all States was 4.0 percent. Delaware also had a decrease in forest lands (5.1 percent), as did Maryland (3.5 percent), Pennsylvania (0.2 percent), and Virginia (1.0 percent). In West Virginia forest cover increased by 1.6 percent. West Virginia had the largest percentage land-use change—an increase of 53.3 percent due to percent increases in urban lands (49.6), forest cover (1.62), water-body acreage (1.96), and Federal lands (0.08), and decreases of 21.1 percent in croplands and 19.53 percent in pasturelands.

*Change in Forest Land Ownership Patterns*

Parcelization is the breaking-up of single contiguous land ownerships into smaller tracts or parcels with increased numbers of owners. The number of average acres per owner in the MAIA region decreased by 1.18 acres (about 8 percent) from 1978 to 1994 (fig. 14).

The largest average decreases by owner were 27.3 acres in Maryland (61.1 percent), 13.5 acres in Delaware (40.3 percent), 7.5 acres in New Jersey (33 percent), and some slight average owner increases of 2.9 acres in Pennsylvania (0.4 percent) and 3.0 acres in West Virginia (4.6 percent). The number of private owners for the entire region increased by 11 percent, while the number of acres of forest land in private ownership increased by only 2 percent during the same period.

Another way of evaluating parcelization is the number of owners and acres by parcel. In 1994 there were still a

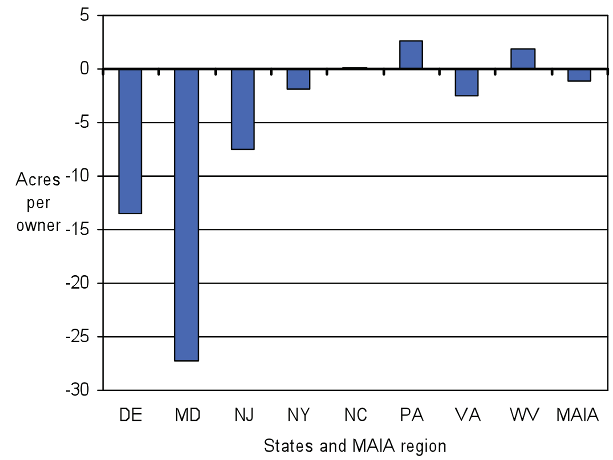


Figure 14— Change in number of acres per owner of forest land by State and MAIA region 1978 to 1994.
Source: Chapter 11, Figure 43.

significant number of large forest tracts greater then 1000 acres in the MAIA region owned by 0.1 percent of all owners, representing 7.2 percent of all forestlands, and some very large tracts greater then 5000 acres owned by only 0.03 percent of all owners and accounting for 13.9 percent of all forestlands. The smallest forest parcels of from 1 to 19 acres belonged to 74.2 percent of all owners, and accounted for only 12.7 percent of all forest land. Owners of parcels 20 to 999 acres represented 25.8 percent of all owners and represented 66.1 percent of all forest land.

These data suggest that parcelization is continuing in most of the region—ultimately it will lead to further fragmentation of forestlands. Increasing population densities will lead to increasing parcelization that will eventually reduce the size of forested land managed for forest production. If these trends continue, the quantity and quality of wood supplies from the MAIA region will decline.

*Fragmentation*

The conversion of forests into crop and pasture lands to support growing populations in the 18th and 19th centuries had the greatest impact on forest fragmentation, because many of these lands were later converted to urban development. Increased urbanization include loss of forest cover and increased impervious surface areas which, in turn, lead to a heightened likeliness of flash flooding and volume of downstream flows, better access for exotic invasive species, and more human disturbance of what little forest remains.

Fragmentation is the breaking-up of larger contiguous blocks of forestlands into smaller, unconnected patches. Increasing population growth typically results in the conversion and fragmentation of forest land to urban development (almost always a permanent conversion) or agriculture and pasture (which can revert back to forest or become urban development). Forestry practices often also fragment the forest, but generally the land remains forested although forest size, shape, structure, and species composition may change. Some of the ecological consequences of forest fragmentation included: (1) loss or change in quality of habitat; (2) increased sedimentation and degradation of streams and aquatic systems; (3) increased numbers of edge-dwelling wildlife species; (4) decreased forest connectivity; (5) increased opportunities for human-wildlife conflicts; and (6) species extinction or loss of species diversity.

Forest management practices in the MAIA region had much lower impact on the degree of fragmentation than urban or agricultural uses. Generally, areas with high levels of forest fragmentation were found in areas of net growth in population, high population density, and net loss of forest lands (fig. 11 b.). Increased population density increased forest fragmentation as city centers expanded, and rings of low-density housing at the edge of cities, often referred to as the urban-rural interface, moved into forested areas. Agricultural and forest-related uses increased, and forest fragmentation decreased appreciably with increasing distance from urban centers, particularly away from coastal areas. Generally then, much of the MAIA landscape was characterized by low (10 to 59 percent) and medium (60 to 89 percent) forest cover and low (< 10 percent) or medium (20 to 59 percent) levels of forest fragmentation, except near urban areas where the fragmentation was greater than 90 percent.

Not only was the quantity of forest land reduced, but the quality of forest habitat was also diminished as patterns of loss transformed the forest landscape into small, isolated patches of trees. As forest loss and fragmentation increase, remaining forest patches become smaller and more isolated, the amount of high quality interior forest habitat is reduced, overall forest connectivity is negatively affected, and the safe movement of wildlife between remaining forest patches is impeded.

Urban growth in the Mid-Atlantic States was concentrated in three regions: (1) the Allegheny Plateau; (2) along the Interstate 95 corridor from Philadelphia, PA, to Raleigh, NC, and 3) the Piedmont, Blue Ridge Mountains, and Northern Ridge and Valley region (figs. 4, 10 b., and 11 b.). Watersheds in the first two regions contained some of the most densely populated urban centers in the East, including Erie and Philadelphia, PA; Newark, NJ; Baltimore, MD; Washington, DC; and Norfolk-Chesapeake, VA. Forest cover in all three regions was low and highly fragmented—the remaining forest patches were small and had little high quality interior forest habitat.

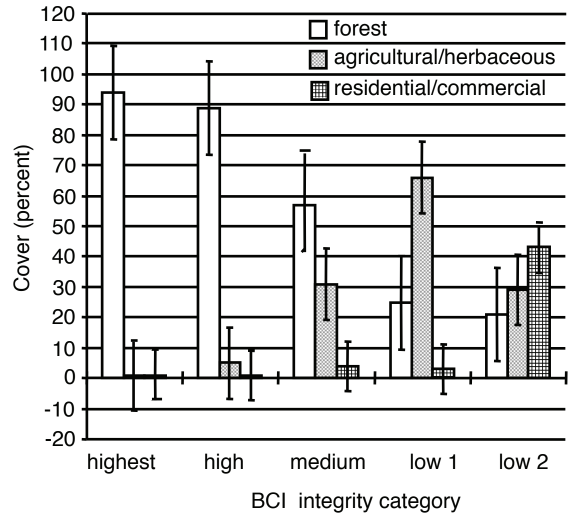


Figure 15—Mean and standard deviation of percent forested, agricultural-herbaceous and residential-commercial land cover of sites in condition categories determined by the Bird Community Index (BCI).
Source: Chapter 12, Figure 49.

Bird community index (BCI) information addresses the overall ecological condition of forests based on forest composition, structure, and function. Analysis of BCI data showed that the species richness of songbirds in the MAIA region decreased significantly as forest fragmentation increased and the proportion of edge habitat increased (fig. 15).

Forest fragmentation was strongly associated with a high proportion of exotic bird species, nest predators and parasites, and *multi-brood* species whose ecological strategy of rapid proliferation leads to reduced numbers of native bird species. Analyses of behavioral and physiological attributes of bird communities at 126 sites in the highlands of the MAIA region indicated that 27 percent of this region was in good condition, 36 percent in fair condition, and 21 percent in poor condition.

## Forest Vitality

Forest vitality refers to the overall vigor and condition of forests. It is generally related to the resilience of a forest to withstand or recover from infrequent but historic stressors (e.g., violent storms) that have co-evolved with the system, and to withstand some level of new forces introduced into the system (e.g., air pollution). A forest in a vigorous condition will often be less impacted by unusually high or severe stressors introduced into the system. Trees are the keystone species in forests because they are the primary source of new carbon and energy entering the system, and the structural foundation of the system. Trees under stress have reduced capacity to fix carbon, and consequently reduced carbon and energy are available to the forest ecosystem. Thus trees are often examined as a leading indicator of the overall vigor of the system.

For example, an epidemic outbreak of native insects will be less devastating if the tree species attacked is in generally good condition. Conversely, the same insect epidemic would be more devastating if the same tree species had already been impacted by an unusually severe drought, impaired nutrient cycling as a result of soil acidification, and so on. Tree condition can be determined by the tree crowns, existing levels of damage, growth, mortality, regeneration, and the type and amount of down dead wood, etc. For example the degradation of tree foliage is a symptom that some stressor(s) are affecting the ability of trees to convert the energy from sunlight into food and structural materials necessary for the health and sustainability of the forest ecosystem.

Vitality also includes attributes of key processes that underlay the structure and function of forest ecosystems. These processes are generally responsive to a variety of stressors that negatively impact forests, and the type of observed effects can be an indication of the causal agent(s) negatively affecting the forest. For example, changes in nutrient cycling will negatively affect the vitality of many forest ecosystem components, and may be caused by increasing soil acidity due to deposition of toxic air pollutants. Thus forest vitality can be evaluated based on indicators related to the type and magnitude of stressors, and whether stressors are increasing, stable, or decreasing. Other forest vitality indicators assess the response of forest ecosystems to stressors, and whether conditions are improving, remaining stable, or are degrading.

## Tree Crown Condition

Trees with dense, full crowns generally have relatively high total leaf surface areas and produce dark shade below the trees. Substantial loss of leaf surface area reduces light interception, the amount of carbon fixed as sugars, and subsequently tree growth, the flow of carbon and energy to other forest species, and overall forest vitality. Thus trees with relatively full, highly-foliated crowns are indicative of relatively low levels of stressors and a greater resilience to any new stressors because the trees are physiologically more active and have more material and energy reserves. Two primary indicators used to assess tree crown condition are crown dieback and foliar transparency.

Dieback is the mortality of small twigs (less than 1 inch in diameter) in the upper, sunlight growing portion of the tree crown. Dieback is often indicative of significant current stressors (e.g., lack of nutrients; drought conditions) and the lack of resources to maintain new growth on trees, or stressors have directly killed these growing tips (e.g., late spring freeze; insect predation). Foliar transparency is related to the size and amount of foliage throughout the tree crown. Tree crowns with high transparency often have smaller leaves that are sparsely distributed where they occur. Transparency is only evaluated on branches where the foliage is present. Dieback and transparency are often evaluated for hardwood and softwoods separately because of the physiological differences between these two major tree groups. The current amount and the amount of change over time are two typical ways of evaluating these crown indicators. Changes over time for 1991 to 1998 or 1995 to 1998 varied by State.

Most of the ecoregion sections in the MAIA region had relatively low average hardwood transparency levels of 12 to 19 percent in 1999 compared to other ecoregion sections in the US where transparency levels were as high as 42 percent. Only a few scattered plots had relatively high transparency levels of 38.1 to 58 percent. However, average hardwood transparency was increasing between 0.1 to 2.0 percent throughout much of the eastern MAIA region, but decreasing by 0 to minus 2.0 percent in the western MAIA region (fig. 16).

Average hardwood dieback was very low at 2.8 to 4.7 percent throughout most of the MAIA region, and even the highest average dieback values of 4.7 to 7.0 percent in the Region

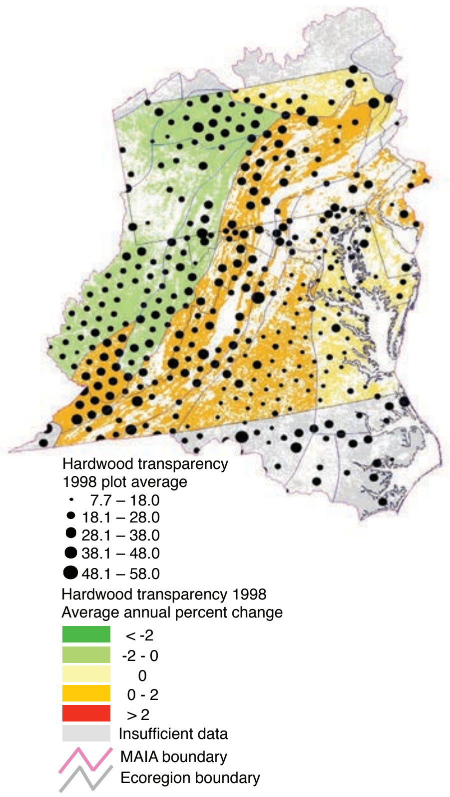


Figure 16— Average annual change in percent foliar transparency of hardwood tree for the period of record for each State by ecoregion section (colored polygons), derived from the average foliar transparency of hardwood crowns at each FHM plot (solid black dots) in each ecoregion section in 1998. The plot value was the actual value if the plot was measured in 1998, and an estimated value based on previous plot measurements otherwise. Note legend also shows annual percent change in hardwood foliar transparency for ecoregion sections outside of the MAIA region for perspective. Data collected 1991-1998 in Delaware, Maryland, New Jersey, and Virginia; in Pennsylvania in 1995 and 1998; in North Carolina in 1998.
Source: Chapter 13, Figure 53.

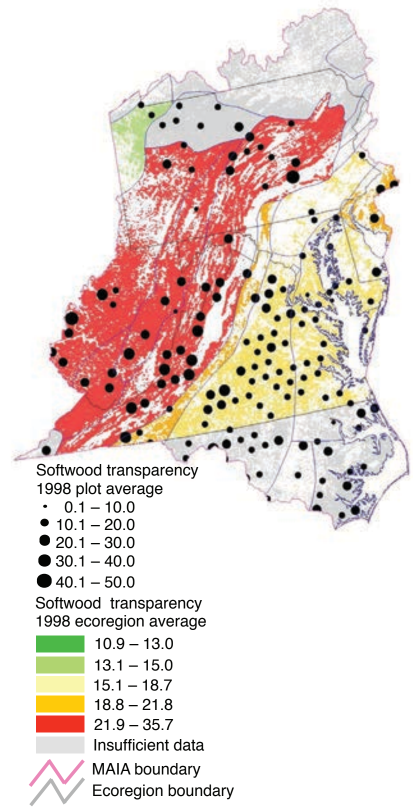


Figure 17—Average percent foliar transparency of softwood trees in 1998 by ecoregion section (colored polygons). The black circles show the average softwood foliar transparency at each FHM plot in 1998; the plot value is the actual value if the plot were measured in 1998 and an estimated value based on previous measurements otherwise. Data collected 1991-1998 in Delaware, Maryland, New Jersey, and Virginia; in Pennsylvania in 1995 and 1998; in North Carolina in 1998.
Source: Chapter 13, Figure 56.

were low compared to hardwoods in other parts of the US. Hardwood dieback levels had decreased or were staying about the same in most of the MAIA region, with some increases of 0.1 to 2 percent per year in the northeastern Pennsylvania region, and decreased 0.1 to 2 percent per year in much of the eastern MAIA region.

Average transparency of softwood trees in the Southern Unglaciated Allegheny Plateau, Northern Ridge and Valley, Allegheny Mountains, and Northern Cumberland Mountains ecoregion sections the Appalachian Mountain were 21.8 to 35.7 percent, the highest observed in the eastern U.S. (fig. 17). Softwood transparency was also relatively high at 15.0 to 18.7 percent throughout much of the eastern MAIA region. Average softwood foliar transparency had increased by 0.1 to 2 percent per year in much of the MAIA region, and increased by greater than 2 percent per year in the Allegheny and Northern Cumberland mountain ecoregion sections.

High softwood crown transparency values were often associated with Virginia pine. This and other data indicated a real decline in the crown condition of Virginia pine throughout the region. Other softwood species with high foliar transparency included shortleaf pine, table mountain pine, and pitch pine. Natural pests and anthropogenic stressors may be contributing to declining health of the pines in this area, but another reason may be the age structure of pine stands. Most of the pine stands in the region originated between 1880 and 1920 during the period of intense farm abandonment and reforestation. For a variety of reasons, there have been only a few young pine stands replacing these older, senescing stands succeeding to hardwoods. If these trends continued, the affected pine species would probably become a significantly smaller component of forests in the western MAIA region.

Average crown dieback of softwood trees was highest at 4.6 to 6.7 percent in the Northern Ridge and Valley, and the Southern Unglaciated Allegheny Plateau ecoregions, as well as the Upper Atlantic Coastal Plain of New Jersey and Delaware. Most of the Coastal Plain and Piedmont had low dieback levels of 0.1 to 3 percent relative to other parts of the country, where softwood dieback average levels as high as 6.7 to 19 percent have been observed. Average dieback levels were higher at 4.6 to 6.7 percent in the Northern Ridge and Valley and Southern Unglaciated Allegheny Plateau ecoregion sections, the latter the only ecoregion section where softwood crown dieback has increased by 0.1 to 2.0 percent per year. Softwood crown dieback was unchanging throughout the rest of the MAIA region.

### Hardwood and Softwood Crown Condition in Watersheds

We also evaluated the condition of hardwood and softwood tree crowns by HUC-4 watersheds in the MAIA region, because watersheds are based on topographic features that cut across different ecoregion section boundaries and are sometimes reflective of stressors that are influenced by topographic features, such as air pollution. It also produces a basis for comparisons of forest condition with water quality condition in the MAIA region.

Average hardwood foliar transparency was highest at 18.1 to 19.4 percent in the lower Susquehanna River, Monongahela River, Kanawha River, Big Sandy and Guyandotte Rivers, and the Upper Tennessee River watersheds. These values were similar to the highest average hardwood transparency values by ecoregion section, but did spatially locate areas of concern better by identifying an area of affected watersheds that ran from the southwest to northwest part of the Region.

Average softwood transparency was highest at 25.1 to 31.7 in the Monongahela River, Kanawha River, Big Sandy and Guyandotte Rivers watersheds, and were high at 18.1 to 25.0 percent throughout the eastern MAIA watersheds. Spatial patterns were similar to those in ecoregion section analyses. Average softwood dieback by watersheds was low throughout the MAIA region, but spatially more pronounced in southern watersheds compared to spatial patterns found by ecoregion section.

In general, analyzing crown condition by watershed sometimes changed and focused the spatial patterns of affected areas, and likely will assist in identifying causal agents and relating forest condition to water quality.

### Tree Damage

Damage caused by pathogens, insects, storms, and human activities can significantly affect the growth, reproduction, and survival of trees. Damages were recorded on each tree if it was likely to lead to infection by lethal pathogens, affect growth and/or reproduction, or cause premature mortality. Generally the type, severity, and location of damages are recorded, and this combination is used to calculate a damage severity index (DSI) score for each tree. All three factors are important. For example, a physical wound near the base of the tree is more likely to negatively impact the tree then the same wound on the top of the tree would. Individual tree damage index scores rarely exceeded 90; trees usually died before damage levels got much higher. Generally, a high damage index indicates multiple damages of high severity often near the bottom of the tree.

The average number of softwood damaged trees and average DSI values were low throughout the MAIA region watersheds. No watershed had more than 20 percent average softwood trees damaged, many plots had zero damage, and plots with damage had DSI scores of 20 or less. The average number of hardwood trees damaged was highest at 20 to 30 percent in northern watersheds and the Pamlico watershed in the southeast MAIA region, but still relatively low compared with values observed in other US forests. There were scattered individual plots with very high average DSI values of 40.1 to 67.5, but many plots with zero or very low DSI scores. Scattered plots with high damage scores were probably related to localized outbreaks of insects or pathogens, storm events, or other causal agents.

### Tree Mortality

Loss of trees and wood volume due to mortality is a natural part of any healthy and sustainable forest ecosystem. We evaluate tree mortality based on the volume of wood lost due to death compared to volume of wood gained in growth of surviving tress, and compute a mortality ratio (MRATIO)

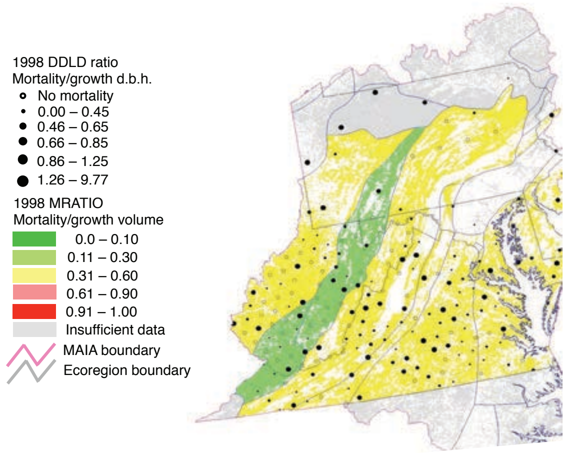


Figure 18—Tree mortality volume by ecoregion section expressed as the ratio of annual mortality volume to annual growth volume (colored polygons). Mortality ratio volumes of 1.0 indicate that there was no net gain in tree volume on the plot. Closed black circles represent plot-level values of the ratio of the average diameter of trees that died to the average diameter of the surviving trees on each plot (DDLD ratios). DDLD ratios of 1.0 indicate that on average the trees that died were as large as the surviving trees. Data collected 1991-1998 in Delaware, Maryland, New Jersey, and Virginia; in Pennsylvania in 1995 and 1998.
Source: Chapter 13, Figure 66.

that quickly summarizes how much wood is being gained in forests each year. For example, an MRATIO of 0.6 means that for every 1.0 cubic foot of wood gained in annual growth, 0.6 cubic feet of wood was lost to mortality, and thus the net gain was 0.4 cubic feet. An MRATIO value greater than 1.0 indicates that the volume of wood lost due to mortality is exceeding the volume of wood gained in growth of surviving trees, and thus the live standing volume of wood is actually decreasing in that location. The MRATIO can be large if an over-mature forest is senescing and losing a large cohort of older, bigger trees. If forests are not naturally senescing, a high MRATIO (greater than 0.6) may indicate high mortality due to some acute cause (insects or pathogens), or other generally deteriorating forest health conditions.

Another ecologically-significant component of tree mortality is the size of the trees that die relative to the size of surviving trees, and thus is related to MRATIO. The dead tree diameters (at breast height) (DD) is compared to the live tree diameters (LD) as an average ratio (DDLD) whenever tree mortality is found on a plot. Low (less than 1) DDLD ratios usually indicate competition-induced mortality of small trees that typically occurs in young, vigorous stands. Higher DDLD ratios (greater than 1) indicate mortality of larger trees that can be associated with senescence or some external stress factors such as insects or pathogens.

Combined hardwood and softwood trees had moderate 0.3 to 0.6 MRATIO values throughout most of the ecoregion sections in the MAIA region (fig. 18). The MRATIOs were lowest (0.10 to 0.30) in the Allegheny Mountains and the Northern Cumberland Mountains. There were many plots throughout the Region with little or no mortality, a number of scattered plots with high DDLD ratios of 1.3 to 9.8 indicating that larger trees had died, and a number of plots with low DDLD ratios less than 0.6 where smaller trees had died.

Evaluation of tree mortality by watershed indicated similar spatial patterns with the exception of the Allegheny River where MRATIO values were 0.61 to 0.8, indicating relatively low gains in wood volume due to tree mortality. However, there were few plots in this watershed. DDLD ratios in this watershed were also high, but results are tempered by the relatively few plots available for mortality analysis in this watershed.

The condition of trees in the MAIA region was generally fair, because there were some concerns with the amount of foliage (foliage transparency) on both hardwoods and softwoods trees. Hardwood transparency was relatively low but increasing annually in much of the Region. Softwood transparency levels were relatively high and also increasing throughout much of the Region. Average tree damage in watersheds were generally low for softwoods, with less than 20 percent of the trees damaged, and slightly higher for hardwoods with 20 to 30 percent of trees showing damage. The mortality of trees in the MAIA region was relatively low to moderate in many areas, suggesting that whatever was causing the poor crown conditions in softwood trees had not yet been of a magnitude to cause significant mortality in the affected species throughout the Region.

## PRODUCTIVITY

The productivity of a forest is often a very good indicator of the general health and sustainability of an ecosystem, because it is an overall indication of factors such as tree health, soil condition, low levels of insects and pathogens, and other factors. It indicates that the amount of carbon being fixed is sufficient to meet the demands for basic maintenance of systems, with a surplus of carbon and energy available to add new wood and support other components of the ecosystem dependent on trees. Productive forests are usually vigorous and healthy systems—when combined with high biological diversity they are good for recreation, wildlife habitat, and timber and non-timber products—as well as aesthetically pleasing.

The productivity of a forest is influenced by many factors: the age of the forest stands, soil conditions, temperature, precipitation, and the presence of stressors that affect tree health. Tree productivity in the MAIA region was evaluated by stand age (average age of trees in stand) and stand density (basal area per acre), net growth rates (volume gained minus volume lost to mortality and harvest), and standing volume (volume of wood in cubic feet per acre).

### Stand Age and Density

The average age of forest stands was 60 years, with stand age ranging from 0 to 120 years. About 20 percent of the stands were in an earlier, regenerative stage (most trees less than 5 inches in d.b.h.)—these were primarily loblolly–shortleaf plantation stands in a regenerative-to-immature age stage (most trees 5 to 10 inches d.b.h.) in the southeastern MAIA region. The most mature stands were oak–hickory types in West Virginia and western Pennsylvania and oak–gum–cypress forests in the coastal plains of Virginia and North Carolina, with over half of these stands containing trees that were mostly greater than 10 inches in diameter. Stand density averaged 100 square feet per acre. The densest stands were oak–gum–cypress with a stand density of 250 square feet per acre.

### Net Growth and Standing Volume

The average net growth rate of forests in the MAIA region was 50 cubic feet of wood volume per acre each year, with individual stands ranging from 0 to 200 cubic feet per acre per year. The loblolly–shortleaf stands had the highest annual net growth rate of 90 cubic feet per acre per year, expected in relatively younger stands managed for timber production. Maple–beech–birch forest types had the lowest average net growth of 30 cubic feet per acre per year, reflecting the cooler temperatures and shorter growing season of these northern forest types.

The standing volume of wood in forest stands reflects the age of the stand, the density of trees in the stand, and the general net growth rates (fig. 19). Average standing volume of all forests in the MAIA region was 1800 cubic feet per acre. Counties with high standing volume of greater than 1900 cubic feet per acre were found in northern Pennsylvania, West Virginia, and parts of the southeast coast. The oak–gum–cypress forests of the coastal plains had the highest average of 2400 cubic feet per acre. Loblolly–shortleaf forest types had on average 1800 cubic feet per acre, similar to the average for all forest types in the MAIA region.

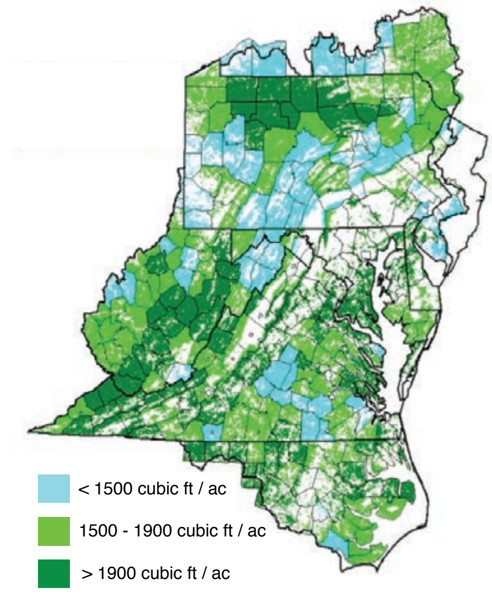


Figure 19—Forest stand volume in MAIA counties as average tree volume in cubic feet per acre prior to 2000.
Source: Chapter 14, Figure 69.

### Market Benefits and Forest Economics

**Timber production**—The variety of timber products, change over time, and spatial patterns of timber produced from 1970 to 1990 constituted timber production for the MAIA region. It was necessary to use data from diverse surveys of wood-product manufacturers that were conducted in different years for different products in different States, so we compiled information for 1970, 1980, and 1990 decades as common periods of reference. Data from the most recent survey in each decade was used to estimate annual timber production in each decade. Sawlog production data for 1990 was only available for New York, North Carolina, and Virginia, so analysis of general timber production trends for the whole MAIA region was limited to 1970 and 1980.

**Quantities of sawlogs and pulpwood**—Annual timber production in the MAIA region was 1,021 million cubic feet (mmcf) during the 1970s, and increased to 1,137 mmcf in the 1980s; it was 978 mmcf in the 1990s for NY, NC, and VA only (table 5).

Softwood and hardwood sawlogs constituted 60 percent of total timber production in the 1970s, and declined by 6 percent to 54 percent in the 1980s. Total pulpwood

**Table 5—Annual hardwood and softwood sawlog and pulpwood production in MAIA region States in the 1970s, 80s, and 90s (Source: Chapter 15, Table 16)**

| Region | Year[a] | Softwood Sawlogs | Softwood Pulpwood | Softwood Total | Hardwood Sawlogs | Hardwood Pulpwood | Hardwood Total | Grand Total | Share of Total MAIA production |
|---|---|---|---|---|---|---|---|---|---|
| | | -------million cubic feet-------- | | | ----- million cubic feet------ | | | -mmcf[d]- | ---percent-- |
| Delaware | | | | | | | | | |
| | 1970 | 1.0 | 3.8 | 4.8 | 1.0 | 0.9 | 1.9 | 6.6 | 0.7 |
| | 1980 | 0.4 | 1.5 | 1.9 | 2. 5 | 0.2 | 2.7 | 4.6 | 0.4 |
| | 1990 | *NA*[b] | 2.1 | *NA* | *NA* | 0.6 | 0.6 | *NA* | *NA* |
| Maryland | | | | | | | | | |
| | 1970 | 5.3 | 14.8 | 20.1 | 18.3 | 9.1 | 27.4 | 47.5 | 4.7 |
| | 1980 | 6 | 17.9 | 23.9 | 16.2 | 10.3 | 26.5 | 50.4 | 4.4 |
| | 1990 | *NA* | 8.6 | *NA* | *NA* | 7.4 | 7.4 | *NA* | *NA* |
| New Jersey | | | | | | | | | |
| | 1970 | 0. 5 | 1.8 | 2.3 | 2.5 | 0.09 | 2.6 | 4.8 | 0.5 |
| | 1980 | 0.3 | 0.8 | 1.1 | 2 | 0.2 | 2.2 | 3.3 | 0.3 |
| | 1990 | *NA* | 0.1 | *NA* | *NA* | 0.01 | 0.01 | *NA* | *NA* |
| New York | | | | | | | | | |
| | 1970 | 6.1 | 3.2 | 9.3 | 56.8 | 3.7 | 60.5 | 69.8 | 6.8 |
| | 1980 | *NA* | 5.8 | 5.8 | *NA* | 4.5 | 4.5 | *NA* | *NA* |
| | 1990 | 9.5 | 5.2 | 14.7 | 40 | 4.7 | 44.7 | 59.4 | NA |
| North Carolina | | | | | | | | | |
| | 1970 | 111.1 | 73.8 | 184.9 | 36.2 | 48.4 | 84.6 | 269.5 | 26.4 |
| | 1980 | 127.2 | 118.3 | 245.5 | 43.2 | 76.6 | 119.8 | 365.3 | 32.1 |
| | 1990 | 165.9 | 104.7 | 270.6 | 49.3 | 92.2 | 141.5 | 412.1 | *NA* |
| Pennsylvania | | | | | | | | | |
| | 1970 | 8.7 | 4.8 | 13.5 | 95 | 72.5 | 167.5 | 181 | 17.7 |
| | 1980 | 7.2 | 4.7 | 11.9 | 109.4 | 91.8 | 201.2 | 213.1 | 18.7 |
| | 1990 | *NA* | 4.9 | *NA* | *NA* | 55 | 55 | *NA* | *NA* |
| Virginia | | | | | | | | | |
| | 1970 | 91.4 | 67.9 | 159.3 | 108.3 | 70.8 | 179.1 | 338.4 | 33.2 |
| | 1980 | 92 | 94.2 | 186.2 | 130.6 | 83.5 | 214.1 | 400.3 | 35.2 |
| | 1990 | 92.6 | 105.1 | 197.7 | 113 | 84.4 | 197.4 | 395.1 | *NA* |
| West Virginia | | | | | | | | | |
| | 1970 | 2.9 | 5 | 7.9 | 69.3 | 25.8 | 95.1 | 103 | 10.1 |
| | 1980 | 0.99 | 5.9 | 6.89 | 76 | 17.2 | 93.2 | 100.1 | 8.8 |
| | 1990 | *NA* | 7.9 | *NA* | *NA* | 24.7 | 24.7 | *NA* | *NA* |
| Mid-Atlantic Region | | | | | | | | | |
| | 1970 | 226.9 | 175.1 | 402.0 | 387.4 | 231.3 | 618.7 | 1020.7 | ----- |
| | 1980 | 234.1 | 249.1 | 477.4 | 379.9 | 284.3 | 659.7 | 1137.1 | ----- |
| | 1990[c] | 268.0 | 238.6 | 506.6 | 202.3 | 269.0 | 471.3 | 977.9 | ----- |

[a]Surveys were conducted in different years for different products. The decades of 1970, 1980 and 1990 were considered a common point of reference. The data from the most recent survey in that decade is used for reporting sawlog production. Pulpwood production corresponding to that timeframe, or closest to that timeframe, is reported.

[b]NA = Not available.

[c]Includes only New York, Virginia, and North Carolina for 1990.

[d]mmcf = million cubic feet.

Source: Timber Product Output and pulpwood surveys conducted by the USDA Forest Service; (http://fa.fed.us).

**Table 6—Average annual sawlog removals of species and species-groups in MAIA region and States in 1980s (Source: Chapter 15, Table 17)**

| SPECIES | WV | WV | MD | MD | DE | DE | NJ | NJ | VA | VA | PA | PA | NY | NY | NC | NC | MAIA Region | MAIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | --mmcf[a]--- | --%[b]-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- | --mmcf-- | --%-- |
| Softwoods | | | | | | | | | | | | | | | | | | |
| Hemlock | 6824 | 20.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21495 | 56.8 | 14864.5 | 32.8 | 0 | 0 | 43294 | 1.9 |
| Yellow pines | 11275 | 34.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 852.5 | 1.9 | 160500 | 13.4 | 172664 | 7.8 |
| White and red pine | 159 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 91650 | 10.9 | 13147 | 34.8 | 20009.6 | 44.1 | 3900 | 0.3 | 128956 | 5.8 |
| Shortleaf/loblolly | 0 | 0 | 46945 | 82.8 | 13843 | 90.9 | 0 | 0 | 16514 | 2.0 | 3172 | 8.4 | 0 | 0 | 991900 | 82.9 | 1072558 | 48.1 |
| Spruce-balsam fir-cypress | 14355 | 44.0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 6991 | 15.4 | 33800 | 2.8 | 55205 | 2.5 |
| Other softwoods | 0 | 0.0 | 9734 | 17.2 | 1393 | 9.1 | 0 | 0 | 734348 | 87.2 | 0 | 0 | 2663.9 | 5.9 | 6600 | 0.6 | 754858 | 33.9 |
| Total softwoods | 32,613 | 100 | 56,679 | 100 | 15,236 | 100 | 0 | 0 | 842,512 | 100 | 37,814 | 100 | 45,382 | 100 | 1,196,700 | 100 | 2,227,536 | 100 |
| Hardwoods | | | | | | | | | | | | | | | | | | |
| Yellow/sweet birch | 6254 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8693 | 1 | 2109 | 1 | 0 | 0 | 17060 | 0 |
| Hickory | 18124 | 4 | 5913 | 2 | 0 | 0 | | 0 | 48264 | 4 | 16549 | 2 | 5746 | 2 | 22700 | 3 | 117311 | 3 |
| Beech | 25175 | 6 | 1407 | 1 | 0 | 0 | 1063 | 8 | 0 | 0 | 23802 | 3 | 21531 | 9 | 8000 | 1 | 81005 | 2 |
| Yellow poplar | 59219 | 14 | 110277 | 41 | 0 | 0 | 1436 | 11 | 282073 | 24 | 46246 | 7 | 3464 | 1 | 173000 | 21 | 675814 | 19 |
| Other hardwoods | 19956 | 5 | 50094 | 19 | 4392 | 34 | 0 | 0 | 126282 | 11 | 28623 | 4 | 36513 | 15 | 23300 | 3 | 289248 | 8 |
| Sweet gum | 0 | 0 | 16175 | 6 | 1101 | 8 | 1777 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 145500 | 18 | 164582 | 5 |
| Ash-walnut-cherry | 38533 | 9 | 0 | 0 | 0 | 0 | 290 | 2 | 22074 | 2 | 117923 | 17 | 24936 | 10 | 17300 | 2 | 221097 | 6 |
| Select white/red oaks | 107363 | 26 | 49404 | 19 | 3293 | 25 | 1729 | 13 | 299124 | 26 | 59737 | 9 | 60115 | 25 | 126600 | 16 | 707508 | 20 |
| Other white/red oaks | 92475 | 22 | 0 | 0 | 3463 | 27 | 6738 | 52 | 281596 | 24 | 267006 | 38 | 8160 | 3 | 130100 | 16 | 789705 | 22 |
| Hard maple | 40980 | 10 | 33392 | 13 | 717 | 6 | 0 | 0 | 85312 | 7 | 126068 | 18 | 47342 | 20 | 0 | 0 | 333884 | 9 |
| Soft maple | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28971 | 12 | 73400 | 9 | 102383 | 3 |
| Tupelo and blackgum | 3374 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 20667 | 2 | 930 | 0 | 0 | 0 | 85700 | 11 | 110671 | 3 |
| Total hardwoods | 411,453 | 100 | 266,662 | 100 | 12,966 | 100 | 13,033 | 100 | 1,165,392 | 100 | 695,577 | 100 | 238,887 | 100 | 805,600 | 100 | 3,610,267 | 100 |
| Softwood percent | 7 | | 18 | | 5 | | 0 | | 42 | | 5 | | 16 | | 60 | | 38 | |
| Hardwood percent | 93 | | 82 | | 46 | | 100 | | 58 | | 95 | | 84 | | 40 | | 62 | |
| Total | 444,066 | | 323,341 | | 28,202 | | 13,033 | | 2,007,904 | | 733,391 | | 284,268 | | 2,002,300 | | 5,837,802 | |

[a] mmcf = million cubic feet.
[b] percentage of total state production.
Source: USDA Forest Service Eastwide Database. Forest inventories were conducted in different States in different years, hence the table does not have a consistent time period.

production expanded in the region by about 25 percent from the 1970s to the 1980s, and pulpwood share of total production increased from 40 to 46 percent during this same period. Overall the hardwood share of both sawlogs and pulpwood total volume produced was higher than softwoods in the region. Hardwoods accounted for about 62 to 63 percent of all sawlogs produced in 1970s and 1980s.

Virginia accounted for about one third of total timber production in the MAIA region in the 1970s and 1980s, with North Carolina second, even though only 47 counties in northeastern North Carolina were evaluated as part of the MAIA region. Sawlogs accounted for 59 percent of Virginia's timber production in the 1970s, 56 percent in the 1980s, and 52 percent in the 1990s (table 5). North Carolina yielded 26 percent of total production in the 1970s, and 32 percent in the 1980s. By the 1990s, total production of softwood and hardwood sawlogs and pulpwood in North Carolina exceeded Virginia.

Timber production in Pennsylvania was lower than in Virginia and North Carolina, and was dominated by hardwoods, comprising 92 percent (1970s) and 94 percent (1980s) of total timber production (table 5). In contrast, hardwoods comprised about half of Virginia's production, and about a third of North Carolina's total timber production in the 1970s, 80s, and 90s. Other States' contribution to the manufacture of timber products was relatively small. West Virginia produced smaller quantities of sawlogs and pulpwood from softwoods (about 7.9 and 6.9 mmcf) then all the other larger MAIA states in 1970 and 1980, respectively, but production of hardwood sawlogs and pulpwood was about 12 times greater (95 mmcf from hardwoods in 1970 and 93 mmcf in the 1980s). Other MAIA states had a more balanced production of sawlogs and pulpwood from softwoods and hardwoods.

**Sawlog removals of species and species-groups**—The market value of sawlogs depends on a number of factors such as species, physical and chemical characteristics of the wood, availability, and demand. Timber removal records from the USDA Forest Service Eastwide Database provided the volume (in thousand board feet) of sawtimber harvested by species-groups and species, by State and the whole MAIA region, during the 1980s using the average annual sawlog removals from the most recent forest survey in each State (table 6).

The softwood share of total sawlog removals was 38 percent and the hardwood share was 62 percent for the entire MAIA region. Hardwoods were predominant in New Jersey (100 percent), Pennsylvania (95 percent), West Virginia (93 percent), New York (84 percent) and Maryland.

(82 percent (table 6). The softwood share of total removals was greatest only in Delaware (54 percent) and North Carolina (60 percent), and was high in Virginia (42 percent); the proportion of softwood removals in the remaining MAIA States ranged from 0 to 18 percent. Shortleaf and loblolly pines accounted for 48.1 percent of all softwood removals in the region and for softwood sawlog removals in North Carolina and Maryland (about 83 percent each) and Delaware (91 percent). Hemlock accounted for 57 percent of total softwood removals in Pennsylvania and 33 percent in New York.

Red oaks, white oaks, and yellow poplar accounted for nearly 61 percent of total hardwood removals for the region. Yellow poplar sawlog removals were 41 percent of hardwood in Maryland, 24 percent in Virginia, 21 percent in North Carolina, 14 percent in West Virginia, and 11 percent in New Jersey. Sweetgum sawlog removals were 18 percent and 14 percent of the total hardwood removals in North Carolina and New Jersey, respectively, but negligible in other MAIA states. Maple sawlogs were the primary hardwoods removed in New York and Pennsylvania, accounting for 32 percent and 18 percent, respectively, of the total hardwoods in those States. Sawlog removals of the tupelo and black gum species group were important only in North Carolina (11 percent) and Virginia (2 percent). The ash-walnut-cherry species group produced about 17 percent (Pennsylvania) and 10 percent (New York) of total hardwood removals, and less than 2 percent in the remaining States.

**Timber Inventories**—Timber volume is affected by growth, mortality, and removals. The latest FIA surveys of the MAIA region by State before 2000 were used, but included sawlog information in the 1990s for only New York, North Carolina, and Virginia. Inventories were estimated at almost 103 billion cubic feet of growing stock wood of hardwood (80 percent) and softwood (20 percent) trees greater than 5 inches in d.b.h., of which 57.9 billion $ft^3$ (56.3 percent) was in sawlog form (table 7).

This growing stock covered 63.5 million acres of timberland forest, with an average of 1,620 cubic feet per acre. West Virginia (94 percent) and Pennsylvania (91 percent) had the most hardwood growing stock, while the 47 counties of northeastern North Carolina had the most softwood stock (43 percent), followed by Delaware (27 percent), New Jersey (25 percent), and Virginia (25 percent).

**Table 7—Hardwood and softwood growing stock and sawtimber volume in MAIA region States circa 2000 (Source: Chapter 15, Table 18)**

| Growing stock[a] | | | | | | |
|---|---|---|---|---|---|---|
| State | Softwood | Hardwood | Total | Softwood Share | Hardwood Share | State share of MAIA |
| | *million cubic feet* | | | *percent* | | |
| Delaware | 176 | 468 | 644 | 27 | 73 | 0.6 |
| Maryland | 813 | 3,662 | 4,475 | 18 | 82 | 4.4 |
| New Jersey | 521 | 1,522 | 2,042 | 25 | 75 | 2.0 |
| New York | 2,365 | 8,322 | 10,686 | 22 | 78 | 10.4 |
| North Carolina | 6,368 | 8,360 | 14,728 | 43 | 57 | 14.3 |
| Pennsylvania | 2,332 | 22,453 | 24,785 | 9 | 91 | 24.1 |
| Virginia | 6,648 | 19,839 | 26,487 | 25 | 75 | 25.7 |
| West Virginia | 1,219 | 17,823 | 19,041 | 6 | 94 | 18.5 |
| Total MAIA[c] | 20,440 | 82,448 | 102,888 | 20 | 80 | 100 |

| Sawtimber[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| State | Softwood | | Hardwood | | Total | | Softwood share | Hardwood share | State share of MAIA |
| | *mcf* | *pgsv[c]* | *mcf* | *pgsv* | *mcf* | *pgsv* | *percent* | | |
| Delaware | 115 | 65.3 | 239 | 51.1 | 354 | 55.0 | 32 | 68 | 0.6 |
| Maryland | 506 | 62.2 | 2,075 | 56.7 | 2,582 | 57.7 | 20 | 80 | 4.5 |
| New Jersey | 483 | 92.7 | 1,361 | 89.4 | 1,844 | 90.3 | 26 | 74 | 3.2 |
| New York | 1,674 | 70.8 | 3,943 | 47.4 | 5,616 | 52.6 | 30 | 70 | 9.7 |
| North Carolina | 4,204 | 66.0 | 4,810 | 57.8 | 9,014 | 61.2 | 47 | 53 | 15.6 |
| Pennsylvania | 1,557 | 66.8 | 11,144 | 49.6 | 12,701 | 51.2 | 12 | 88 | 21.9 |
| Virginia | 3,801 | 57.2 | 11,506 | 58.0 | 15,307 | 57.8 | 25 | 75 | 26.4 |
| West Virginia | 805 | 66.0 | 9,665 | 54.2 | 10,469 | 55.0 | 8 | 92 | 18.1 |
| Total MAIA | 13,145 | 64.3 | 44,742 | 54.3 | 57,887 | 56.3 | 23 | 77 | 100 |

[a]Growing stock volume is the cubic-foot volume of sound wood in trees at least 5.0-inches dbh from a 1-foot stump to a 4-inch top..
[b]Sawtimber volume is the growing-stock volume in the sawlog portion of sawtimber-size trees:
Softwoods: volume between 1-foot stump and 7-inch top for sawtimber trees 9.0-inches dbh and larger
Hardwoods: volume between 1-foot stump and 9-inch top sawtimber trees11.0-inches dbh and larger.
[c]Percent of growing stock volume.
Source: USDA Forest Service Eastwide Database; Hansen and others 1992.

About 58 billion cubic feet of wood (56 percent) were in a sawlog or sawtimber stage of development (softwoods greater than 9 inches d.b.h.; hardwoods greater than 11 inches d.b.h.); with hardwoods comprising 77 percent and softwoods 23 percent (table 7). States had from 51 to 61 percent of growing stock in sawtimber volume, except New Jersey where sawtimber volume accounted for 90 percent. Virginia and Pennsylvania had the highest hardwood sawtimber volume of over 11 billion cubic feet each, and total sawtimber volume representing 26 and 22 percent, respectively, of the MAIA region volume. North Carolina had the highest volume of softwood sawtimber at over 4 billion cubic feet.

On average, there was an annual increase of 1.4 percent of the total growing stock (trees > 5 inches d.b.h.) in the MAIA region during the period 1970 through 1990. Annual hardwood growing stock increases were 1.8 percent and softwoods 0.89 percent. Total growing stock annual carryover was highest in Maryland (2.8 percent), New Jersey (2.3 percent), and West Virginia (2.3 percent). North Carolina had the lowest annual carryover of only 0.4 percent

**Table 8—Growing stock and sawtimber volume removals, growth, and mortality in MAIA region States circa 2000 (Source: Chapter 15, Table 20)**

| Growing stock | | | | | | | |
|---|---|---|---|---|---|---|---|
| State | Total volume | Average net annual growth | Average annual removal | Average annual mortality | Total volume net growth | Total volume removal | Total volume mortality |
| | *million cubic feet* | | | | *percent* | | |
| Delaware | 643.90 | 13.50 | 3.20 | 4.11 | 2.10 | 0.50 | 0.64 |
| Maryland | 4474.90 | 163.29 | 39.27 | 27.34 | 3.65 | 0.88 | 0.61 |
| New Jersey | 2042.20 | 53.79 | 6.09 | 10.14 | 2.63 | 0.30 | 0.50 |
| New York | 10686.10 | 294.33 | 81.21 | 44.90 | 2.75 | 0.76 | 0.42 |
| N. Carolina | 14727.80 | 594.80 | 536.30 | 96.10 | 4.04 | 3.64 | 0.65 |
| Pennsylvania | 24784.50 | 631.74 | 284.05 | 176.93 | 2.55 | 1.15 | 0.71 |
| Virginia | 26487.00 | 801.61 | 558.72 | 161.33 | 3.03 | 2.11 | 0.61 |
| W. Virginia | 19041.30 | 505.17 | 71.06 | 46.66 | 2.65 | 0.37 | 0.25 |
| Total MAIA | 102887.70 | 3058.23 | 1579.90 | 567.51 | 2.97 | 1.54 | 0.55 |

| Sawtimber | | | | | | | |
|---|---|---|---|---|---|---|---|
| State | Total volume | Average net annual growth | Average annual removal | Average annual mortality | Total volume net growth | Total volume removal | Total volume mortality |
| | *million cubic feet* | | | | *percent* | | |
| Delaware | 354.10 | 45.59 | 28.20 | 11.47 | 12.88 | 7.96 | 3.24 |
| Maryland | 2581.60 | 565.20 | 338.36 | 68.08 | 21.89 | 13.11 | 2.64 |
| New Jersey | 1843.90 | 154.36 | 13.03 | 22.52 | 8.37 | 0.71 | 1.22 |
| New York | 5616.40 | 1053.38 | 284.27 | 97.38 | 18.76 | 5.06 | 1.73 |
| N. Carolina | 9014.00 | 2371.70 | 2002.30 | 235.80 | 26.31 | 22.21 | 2.62 |
| Pennsylvania | 12701.00 | 2441.20 | 942.51 | 339.67 | 19.22 | 7.42 | 2.67 |
| Virginia | 15307.00 | 3270.42 | 2019.34 | 456.64 | 21.37 | 13.19 | 2.98 |
| W. Virginia | 10469.10 | 1978.06 | 444.03 | 101.75 | 18.89 | 4.24 | 0.97 |
| Total MAIA | 57887.10 | 11879.90 | 6072.04 | 1333.32 | 20.52 | 10.49 | 2.30 |

Source: USDA Forest Service, Eastwide Database; Hansen and others 1992.

during this period, but led other MAIA states in the amount of annual increases in hardwood growing stock at 3.0 percent, followed by Maryland at 2.9 percent. All States had average annual increases in softwood growing stock except Virginia (annual decrease of 0.08 percent), with the highest annual increases in Pennsylvania at 2.5 percent.

On average total sawtimber annual increase was high in the MAIA region at 10.0 percent, with hardwood and softwood sawtimber annual increases at 11.0 percent and 6.8 percent, respectively, during the period 1970 through 1990. West Virginia (14.7 percent), New York (13.7 percent), and Pennsylvania (11.8 percent) led the other MAIA states in total annual sawtimber carryover. Annual sawtimber inventories increased in all States, led by West Virginia at 14.7 percent and New York at 13.7 percent. Annual softwood sawtimber inventories increased and were highest in Pennsylvania at 13.3 percent and New York at 12.3 percent, and lowest in Delaware where it decreased by 2.6 percent.

Average net growth of the total growing stock volume was 3.0 percent per year for the MAIA region, with all States above 2 percent and North Carolina highest at 4.0 percent (table 8).

Production intensity is the ratio of average annual removals to growing stock volume and identifies the proportion of growing stock volume removed per year. The average production intensity was 1.5 percent for the MAIA region, led by the southern MAIA region with 3.64 percent in North Carolina and 2.11 percent in Virginia. In the northern MAIA region, only Pennsylvania had a removal ratio greater than one percent at 1.2 percent. All other northern States had an annual average removal rate of less than 1 percent per year. Removals of softwoods were highest in North Carolina at 4.7 percent per year and Virginia at 3.5 percent per year. Hardwood removals were less than 1 percent per year for all States in the region, except for Pennsylvania at 1.2 percent per year and Virginia at 1.6 percent per year.

The production intensity for sawtimber volume averaged 10.5 percent for the MAIA region, led by North Carolina (22.2 percent), Virginia (13.2 percent), and Maryland (13.1 percent) (table 8). The percent increase in sawtimber volume averaged 20.5 percent for the MAIA region, and average annual mortality rates were 2.3 percent. Thus on average annual removals of growing stock volume and sawtimber volume were about half of the annual net increases for the MAIA region, indicating that these forests have been annually increasing volume more then losing volume to mortality and timber harvesting.

**Timber markets**—Timber markets were influenced by supply and demand within the MAIA region and nearby States, Canada, and other markets from 1977 through 1997. The high sawtimber production of Virginia and North Carolina was used primarily for structural lumber, and softwood pulpwood used for paper products. Hardwood sawtimber from central and northern part of the MAIA region was used primarily for the furniture industry, housing industry, and pallet industry. Low quality hardwoods were used primarily for pallets, but were also increasingly used for pulpwood production for paper products. Pennsylvania supplied the most high quality hardwood for the furniture stock used in secondary processing mills in Pennsylvania and other States, particularly for the Southeast. Market interchanges between States within and without the MAIA region were complex, and varied greatly for each State. Details for each State are found in the body of the MAIA report.

## Timber Prices

Timber prices are determined by the law of supply and demand, like many other markets. If demand is up and supply is low, prices generally rise; conversely, if supply is up and demand is low, prices tend to drop. The prices

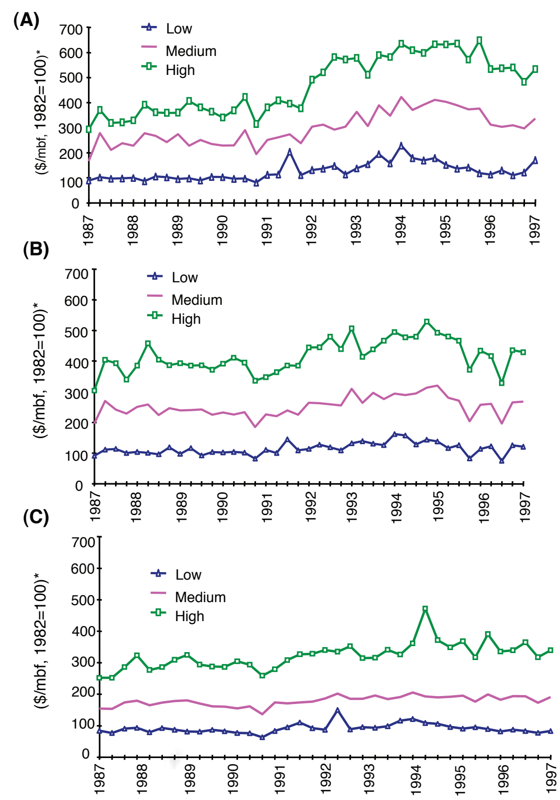


Figure 20—Real prices of delivered black cherry (a), red oak (b), and white oak (c) sawlogs in Pennsylvania from 1987 to 1997, by low, medium, and high grades, corresponding to USFS grades F3, F2, and F1, respectively. *mbf = thousand board feet
Source: Chapter 15, Figures 75, 76, and 77.

recorded in Pennsylvania were considered to be more representative of the northern MAIA region and hardwood prices, while prices in Virginia and North Carolina were considered more representative of the southern part of MAIA region and softwood prices. All prices in the report were adjusted to 1982 values for inflation. The stumpage price is the price of standing trees in the forest, while the mill price is the price of logs delivered to the mills for processing. We primarily used mill prices in comparisons because they more accurately capture the value in the market than stumpage prices.

The mill prices for sawlogs of white oak, red oak, and black cherry by grade (low, medium, high) for Pennsylvania from 1987 to 1997 represented about 62 percent of all hardwoods harvested (fig. 20 a.b.c.). Black cherry—primarily used by the furniture and cabinet industries—had the highest value, and the greatest increase in price from 1977 to 1997 of 13.7 to 17.7 percent per year for low to high grade wood, respectively. Black cherry logs were also the second highest exported species to Europe. The demand for veneer—whether for cabinet, furniture, or architectural millwork—also had increased. Of the total amount of black cherry available in the region, higher quality timber was relatively scarce. Increasing concern for sustainable management of this environmentally and economically important species contributed to declining timber harvests in the Kene National Forest in Pennsylvania, resulting in less cherry timber available in the region and more pressure on the supply. Black cherry has a thin margin: a small increase in demand can affect pricing significantly, even though the total demand volume does not change much. All of these factors, i.e., greater demand in both domestic and international markets, along with reduced supply, combine to make black cherry a very valuable commodity in Pennsylvania.

The demand for sawlogs comes from the demand for products made from them. An understanding of the demand for lumber improves our understanding of the behavior of sawlog prices. Since the early 1970s, red oak has become an important furniture lumber and the dominant species for kitchen cabinets and millwork Prices for species of red oak and white oak sawlogs also increased significantly in Pennsylvania from 1987 to 1997, and prices for higher-grade sawlogs increased faster than for lower grades. High-grade red oak and high-grade white oak grew 5.0 percent and 7.1 percent per year, respectively, compared to medium-grade red oak (4.2 percent), medium-grade white oak (4.4 percent), and low-grade red oak (4.9 percent); all indicated an overall increase in demand for most grades of both red and white oaks. Considerable demand for white oak lumber in the international market may have accounted for the increasing prices of white oak sawlogs in Pennsylvania. In 1981 almost equal volumes of red and white oak were exported to Europe from the U.S.; but by 1990 white oak exports were more than 3.5 times greater than red oak exports. White oak was the most widely exported species to the European market in 1990, and individual market shares for white oak ranged from under 20 percent in Denmark and Italy to more than 80 percent in Spain. Red oak was in high demand in some countries, and accounted for roughly 40 percent of the market in Luxembourg and Belgium, 30 percent in France, and a very small amount in most Scandinavian countries.

Mill prices for softwood sawlogs from North Carolina and Virginia increased about 2.1 and 3.9 percent per year, respectively, from 1977 to 1997, and pine pulpwood prices declined during the same period at an annual rate of 0.74 percent per year in western North Carolina, and 1.08 percent per year in central and far eastern North Carolina.

Total pulpwood production in Pennsylvania increased by about 40 percent between 1968 and 1988. Pulp processors relied heavily on chipped-residues to handle production increases, aided by increased sawlog portions that made manufacturing residue more available. The chipped-residue portion of total pulpwood production increased from 23 to 37 percent from 1968 to 1988. This implied decreased demand for higher and medium-grade pulpwood that resulted in lower prices. However, in 1990, hardwood pulpwood production declined by almost 34 percent compared to 1988 production. And, even though softwood pulpwood increased by about 11 percent in 1990 compared to 1988, the production of hardwood and softwood pulpwood together declined by 32 percent in 1990.

Pine pulpwood production and harvesting increased in North Carolina from 1986 to 1992. Almost all of this growth was in southwestern North Carolina, where softwood pulpwood production expanded by 53 percent. Pulping capacity in that region was relatively small, however, suggesting that mills in Georgia and Tennessee were drawing increasing amounts of material from this region. This implied that hauling distances and zones of procurement for pine pulpwood were expanding, foreshadowing increasing demand for pulpwood timber. Pine pulpwood prices increased in Virginia between 1977 and 1997. They increased at an annual rate of 1.45 percent in western Virginia and 1.73 percent in eastern Virginia. Eighty-four percent of roundwood products cut for pulpwood were retained for processing at Virginia pulp mills. Imports of nearly 49 million cubic feet exceeded exports by 64 percent, making the State a net importer of pulpwood, and suggested that pine pulpwood was relatively scarce in Virginia during those two decades.

## Forest Industry

To quantify the economic importance of forest-based industries in the MAIA region, we examined employment and income generated in the following sectors based on Standard Industry Classifications (SIC): lumber and wood products (SIC 24), furniture and fixtures (SIC 25), and paper and allied products (SIC 26).

Forest industry has been an important contributor to the economy of the MAIA region, producing an average of a quarter million jobs, or 2.04 percent of all wage employment, and generating $4.5 billion in wages and salaries each year between 1975 and 1995 (table 9).

However, with the exception of lumber and woods products in Delaware, West Virginia, and Pennsylvania, and furniture

**Table 9—Average employment (wage and salary) and rate of change in all Standard Industry Classification (SIC) sectors in MAIA region 1975 to 1995 (Source: Chapter 15, Table 24)**

| State/sector | Average employment | Average share of total economy employment | Average annual rate of change |
|---|---|---|---|
| | --*thousands*-- | -----------------*percent* | ------------------ |
| **Total MAIA region** | | | |
| All sectors | 11969.8 | 100 | 1.93 |
| SIC 24[a] | 83.6 | 0.70 | 1.32 |
| SIC 25[b] | 73.1 | 0.61 | 0 |
| SIC 26[a] | 87.4 | 0.73 | 0 |
| Total SIC 24+25+26 | 244.1 | 2.04 | |
| **Delaware** | | | |
| All sectors | 248.3 | 100 | 2.75 |
| SIC 24 | 0.82 | 0.33 | 3.36 |
| SIC 25 | 0.5 | 0.20 | 5.8 |
| SIC 26 | 2.5 | 1.01 | 0 |
| Total SIC 24+25+26 | 3.82 | 1.54 | |
| **Maryland** | | | |
| All sectors | 1455 | 100 | 2.62 |
| SIC 24 | 3.8 | 0.26 | 0 |
| SIC 25 | 3.3 | 0.23 | -1.23 |
| SIC 26 | 9.4 | 0.65 | -0.84 |
| Total SIC 24+25+26 | 16.50 | 1.14 | |
| **New Jersey**[d] | | | |
| All sectors | 1441.2 | 100 | 2.24 |
| SIC 24 | 2.6 | 0.18 | -1.44 |
| SIC 25 | 1.8 | 0.12 | 0 |
| SIC 26 | 6.8 | 0.47 | -1.62 |
| Total SIC 24+25+26 | 11.20 | 0.77 | |
| **New York**[d] | | | |
| All sectors | 972.7 | 100 | 1.93 |
| SIC 24 | 4.7 | 0.48 | 0 |
| SIC 25 | 6.6 | 0.68 | 1.15 |
| SIC 26 | 4.2 | 0.43 | 0.84 |
| Total SIC 24+25+26 | 15.50 | 1.59 | |
| **North Carolina**[d] | | | |
| All sectors | 1439 | 100 | 2.46 |
| SIC 24 | 16.8 | 1.17 | 0 |
| SIC 25 | 16.7 | 1.16 | -1.06 |
| SIC 26 | 6.5 | 0.45 | 1.34 |
| Total SIC 24+25+26 | 40.00 | 2.78 | |

[a] SIC 24 = lumber and wood products
[b] SIC 25 = furniture and fixtures
[c] SIC 26 = paper and allied products
[d] Figures for NJ, NY and NC are totals for the subset of counties in the MAIA region.
Source: Department of Labor, unemployment insurance database ES-202; http://workforcesecurity.doleta.gov/unemploy/finance.asp.

**Table 9—(Continued) Average employment (wage and salary) and rate of change in all Standard Industry Classification (SIC) sectors in MAIA region 1975 to 1995 (Source: Chapter 15, Table 24)**

| | | | |
|---|---|---|---|
| **Pennsylvania** | | | |
| All sectors | 4042.6 | 100 | 0.97 |
| SIC 24 | 25.4 | 0.63 | 2.98 |
| SIC 25 | 19.3 | 0.48 | 0 |
| SIC 26 | 41.3 | 1.02 | -0.43 |
| Total SIC 24+25+26 | 86.0 | 2.13 | |
| **Virginia** | | | |
| All sectors | 1893.3 | 100 | 3.22 |
| SIC 24 | 23.3 | 1.23 | 0 |
| SIC 25 | 24 | 1.27 | -0.95 |
| SIC 26 | 15.5 | 0.82 | 1.21 |
| Total SIC 24+25+26 | 62.80 | 3.32 | |
| **West Virginia** | | | |
| All sectors | 477.7 | 100 | 0 |
| SIC 24 | 6.2 | 1.30 | 2.3 |
| SIC 25 | 0.97 | 0.20 | -2 |
| SIC 26 | 1.3 | 0.27 | -1.92 |
| Total SIC 24+25+26 | 8.47 | 1.77 | |

[a] SIC 24 = lumber and wood products
[b] SIC 25 = furniture and fixtures
[c] SIC 26 = paper and allied products
[d] Figures for NJ, NY and NC are totals for the subset of counties in the MAIA region.
Source: Department of Labor, unemployment insurance database ES-202; http://workforcesecurity.doleta.gov/unemploy/finance.asp.

and fixtures in Delaware, the forest industry sector has not been growing as rapidly as the rest of the MAIA region economy. Several States had even experienced negative rates of growth in some forest industry sectors (e.g., Maryland and New Jersey). As a result, the share of employment in forest industries declined during the last two decades in all states except West Virginia and Delaware.

Real wage and salary income for the entire Region's economy averaged $222.3 billion per year between 1975 and 1995, and about 2.02 percent ($4.50 billion) of that total came from forest industries. The average wage per job increased in all forest industries, despite slight decreases in wages in the early 1980s, and all other sectors between 1975 and 1995 (fig. 21).

The average real wage per job for the entire economy of the MAIA region between 1975 and 1995 was about $18,000—growing from about $16,000 in 1975 to $21,000 in 1995 (an increase of 31 percent). The average wage per job in SIC 24 and SIC 25 was $14,816 and $15,497, respectively;

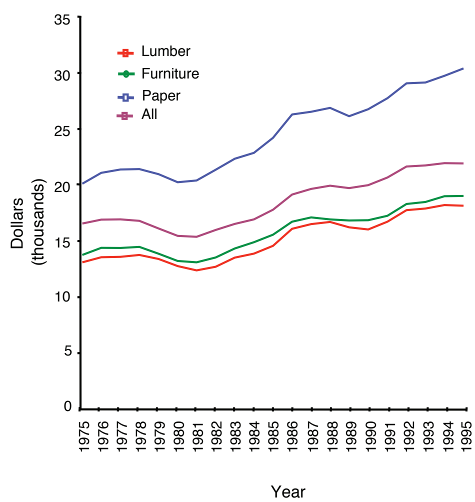


Figure 21—Real wages per job in lumber and wood products (SIC 24), furniture and fixtures (SIC 25), paper and allied products (SIC 26), and all sectors of the MAIA economy 1975 to 1995. Source: Chapter 15, Figure 88.

earnings below the MAIA regional average by 18 and 14 percent, respectively. The average wage per job in SIC 26 was $24,000, higher than the regional average for the entire MAIA economy by almost 33 percent. The wage per job in SIC 26 increased by 52 percent between 1975 and 1995, compared to a 40 percent increase in SIC 24 and a 39 percent increase in SIC 25.

Wages in SIC 24 increased at the highest average annual rate of 3.34 percent per year, SIC 25 followed with 1.35 percent, and SIC 26 with 2.16 percent for the whole MAIA region, compared to average annual rate of 3.81 percent for all other non-forest sectors. The lumber and wood products sector (SIC 24) produced an average of $1.25 billion per year in wages and salaries, SIC 25 generated $1.13 billion, and SIC 26 an average $2.12 billion.

If recent trends continue, the forest industry will continue to be an important source of employment and income for parts of some States in the MAIA region—but forest industry's importance relative to the entire Mid-Atlantic economy will probably continue to decline in the 21st century. Even so, more than half of the total forest area in the MAIA region now contains sawtimber-size stands, which, by timber market standards, represent a valuable resource in a harvestable condition. Most of these harvestable stands were found in Pennsylvania, Virginia, and West Virginia.

## Game Species

Trends in game species populations are also indicators of overall forest health and sustainability. Negative changes in animal populations usually reflect changes in habitat available for wildlife, harvesting pressures, or stress from exotic competitors, diseases, etc. It is imperative that rates of harvest do not exceed rates of population increases so a growing, viable population is present to withstand unforeseen environmental stresses. Excessive harvest rates, combined with degradation of habitat, often lead to catastrophic crashes in wildlife populations. Wildlife in the MAIA region, similar to wildlife populations throughout the eastern U.S., have been recovering from the severe over-harvesting and habitat degradation that led to the near extinction of many species by the beginning of the 20th century.

Current population estimates and rates of harvest of primary game species in the MAIA region indicated populations were robust and in some cases increasing at greater than harvest rates. For example, populations of black bear increased from about 8,000 bears in 1975 to about 23,000 bears in 1993, while harvest levels only increased from about 2,000 bears in 1975 to about 5,000 in 1993. While increased estimates of bear populations may be partially an artifact of improved tracking technologies, it is apparent that bear populations are not in danger of being depleted by current hunting practices. Turkey populations also increased at rates greater than harvest, with a population estimated at 300,000 in 1993 compared with a harvest of about 110,000 for the same year. Squirrel populations have remained relatively constant at 11 million for the same period, while harvest of squirrels has decreased from about 4 million to 2 million per year. The stability of squirrel population estimates, even with declining harvest pressures since 1980, suggests that this species has probably reached the carrying-capacity of environments to support their populations, and populations are more controlled by habitat and other factors then by hunting pressures. White-tailed deer populations exploded from about 2 million in 1980 to about 3.6 million in 1990, while deer harvest levels only increased from 0.5 million to about 1.5 million during the same period (fig. 22). Hopefully, the leveling-off of white-tail deer population at about 3.6 million animals in 1990, despite increases in the number of deer harvested after 1990, may indicate this species has also reached or exceeded the carrying capacity of the environment. The excessive browsing of large populations of white tail deer are causing very negative effects on forests primarily because of the selective feeding on seedlings and saplings of tree species, thus affecting the composition, structure, and function of future forests throughout much of the eastern United States.

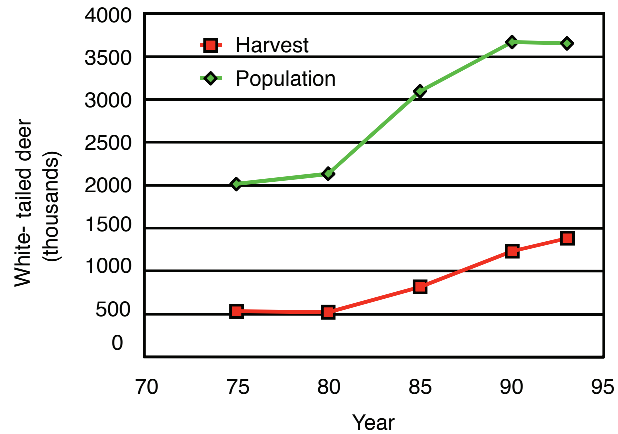

Figure 22—White-tailed deer population and harvest for 1975 to 1993 for all States in the MAIA region. Estimates include counties outside of the MAIA region for New York, New Jersey, and North Carolina.
Source: Chapter 16, Figure 91.

## CONSERVATION OF SOIL AND WATER SYSTEMS

### Soils

Soils are one of the most essential components of healthy and sustainable forest ecosystems. Soils anchor plants to the ground, supply water and essential nutrients, and protect roots from harsh environmental conditions. Soils provide five of the six environmental components that trees and other plants are dependent: mechanical support, heat, air, water, and nutrients. Most of the crucial mineral exchange between the biosphere (world of living creatures) and the inorganic world (rock) occurs in the soil. Dead plants and animals decompose and return mineral nutrients and organic material to the soil. The numerous small organisms responsible for decomposition are abundant in the surface layers of the soil where dead organic matter is most plentiful. The activities of these organisms contribute to the development of soil properties in a surface-to-bottom direction, while physical and chemical decomposition of bedrock contribute to soil development in a bottom-to-surface direction. Both surface and bedrock processes are important for a healthy soil system. Human-induced threats to degradation of forest soils are erosion, acidification through atmospheric deposition, loss of nutrients, accumulation of toxins, and compaction.

Most of the soil is relatively inert, and most of the chemical and biological functions in soil are determined by the clay and organic matter components. Soil analyses in the MAIA region focused on the biological, chemical, and physical processes of mineral soils and organic matter in the upper 20 inches of soil, with most emphasis on the upper 8 inches. This top 8 inches often contains the litter layer, O-horizon, and the A-horizon layers.

Generally the nutrient calcium and magnesium levels in surface soils in the MAIA region were marginal; however there were scattered plots where magnesium levels were relatively low (0.04 to 0.60 milliequivalents per 100 grams). However, the acidity levels (pH values) of the 0 to 4 inch surface and 4.1 to 8 inch subsurface mineral soils were very low at pH values of 3.1 to 4.5 in many areas, indicating high vulnerability to any further acidifications that would reduce nutrient cation availability, increase the availability of toxic aluminum, and result in leaching of nutrient and toxic chemicals into associated aquatic systems.

### Water

The primary concern for the quality of fresh water systems in the MAIA region are the conversion of forested lands to other uses and the resultant increases in soil erosion and stream sedimentation, increases in water flows during storm events, increases in toxic elements, and subsequent changes in stream habitat and biology. Conversion of forest to other land uses was found to degrade stream quality on short-term scales of 2 to 5 years at local spatial scales, but there was no evidence of cumulative effects on stream quality at regional scales from local-scale forest management practices.

The condition of first, second, and third order streams in mountainous watersheds were evaluated as part of EPA's Environmental Monitoring and Assessment Program Mid-Atlantic Highlands stream monitoring program. In first order streams, 97 percent of the area was forested, compared to 80 percent forested for second order streams, and 75 percent forested for third order streams. Thus the total non-forest land use in 1st order streams was 3 percent, compared to 20 percent for 2nd order, and 25 percent for 3rd order streams. Agriculture accounted for about 20 percent of the land area for second and third order streams. Stream orders 1, 2, and 3 all had significant fish populations, with respectively 74 percent, 92 percent, and 93 percent respectively of the stream miles having either fish or sport fish present. The 26 percent of first-order stream miles without fish did not imply stream degradation, but may have simply been inadequate habitat for fish due to steep topography, low flows, and other factors. Highly forested watersheds with better water quality also had better biological condition based on the widely-used indicators of stream quality, the presence of the benthic insects in the Orders *Ephemeroptera, Plecoptera,* and *Trichoptera* (EPT). EPT scores were higher for all stream orders in low land use watersheds, but were only statistically higher in third-order streams (figure 23).

The effects of land use on stream physical and chemical quality was also evaluated by comparing stream orders 1, 2, and 3 in watersheds with greater than 95 percent forested (low landuse) with watersheds less than 95 percent forested (high landuse). The following variables were averaged across stream orders 1, 2, and 3 and compared by ratios of high landuse to low landuse. Thus ratio values of 1.0 meant that there was no difference between watersheds with high landuse compared to low landuse; ratio values of 2.0 meant that watersheds with high landuse had twice the value found in low landuse. The high landuse to low landuse watershed ratios were: road density = 2.3; total suspended solids = 2.4; percent fine clays and silts = 8.6; nitrate = 3.3; and total phosphorus = 2.8. Thus highly forested watersheds contained streams with better physical and chemical water conditions and water quality.

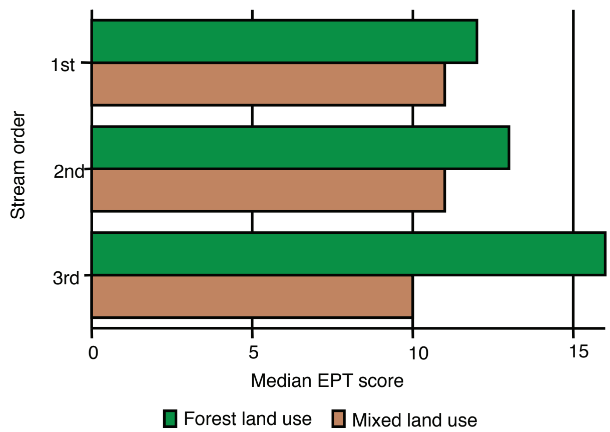


Figure 23—Median Ephemeroptera, Plecoptera, and Trichoptera (EPT) scores by stream order. EPT scores are based on type and number of these three groups of stream insects.
Source: Chapter 18, Figure 101.

The general result was that conversion of forests to other land uses, particularly agriculture, appears to have mainly affected 3rd order streams or higher, with little measurable effects on 2nd or 1st order streams. Thus there was no evidence of regional effects on stream condition from conversion of forest land to other uses, but local effects at the scale of 3rd order streams or higher.

## CARBON CYCLING

Carbon is the biological building block of life on earth, and thus the cycling of carbon is the essential fundamental process in all ecosystems. Changes in expected variances in carbon cycling patterns can reflect major alterations in forest ecosystems. Plants incorporate carbon into biological systems through photosynthesis—energy from sunlight is used to combine carbon dioxide with water and produce simple sugars (molecular chains of carbon atoms) and gives off oxygen as a waste product. Some of this *fixed* (chemically reduced) carbon is burned (chemically oxidized) to produce energy for most biological processes; some is sequestered as part of above and below ground plant biomass; some is used by insects, animals, bacteria, and other organisms for growth, a process known as *secondary productivity;* and some is incorporated as part of the upper soil horizons as organic matter.

Part of the carbon stored in forest systems later is released into the atmosphere as organic matter decomposes over time. Both forest biomass and forest soils serve as large carbon sinks (carbon deposits) and are, therefore, an essential component of a stable ecosystem and global carbon cycles. Approximately one-half of the carbon harvested as biomass is stored for long periods as wood products. A net gain in carbon is the result of high stand-growth rates, relatively low mortality volumes, efficient utilization of harvest trees and salvage of mortality, or some combination thereof.

The amount of carbon stored or lost annually for MD, VA, and WV was estimated for variable periods from 1991 to 1998. Average carbon sequestration rates in woody biomass for this part of the MAIA region was 1,600 lbs per acre per year. Carbon sequestration rates in the MAIA region were highest (greater than 60 $ft^3$ per acre per year) in the middle and lower Atlantic Coastal Plain of the Southeast; moderately high (40 to 60 $feet^3$ per acre per year) in the western and northwestern parts of the region; lower (less then 40 $feet^3$ per acre per year) in the central and north Piedmont areas and western mountain areas; and lowest in the northwestern part of the region.

These patterns of carbon storage are not surprising, because the rate of carbon sequestration in a given area is a function of inherent site quality (high moisture, soil fertility, and moderate temperatures), seral stage of development, and intensity of forest management. The southeastern Coastal Plain has some of the best conditions for tree growth in the U.S., and includes a high proportion of managed forest pine plantations with harvest rotation cycles set to get maximum growth rates.

## BIOLOGICAL DIVERSITY

Biological diversity, sometimes shortened to biodiversity, is of interest over a wide range of spatial and temporal scales from genotypes within a species to mixes of forest types and plant communities at regional, national, and international levels. It can also include the physical or structural arrangement of species within a forest stand. There are numerous ways of assessing biological diversity that are generally based on the number of species, the relative abundance of each species, and the distribution of species within some defined ecological strata.

The amount of biodiversity is always constrained by the conditions found in any environment. Physical and biological factors create potential habitats or spaces for species to occupy that are called *niches.* The primary physical drivers are moisture and temperature; secondarily are topography, geology, and other factors; and thirdly are cyclic disturbances like storms, rockslides, and other events. Environments that are inherently harsh for plants typically have low biodiversity, for example boreal forests; and environments that are milder, for example tropical forests, often have relatively high biodiversity. A fourth factor in the biodiversity framework is that biology itself creates additional niches where more species can be added. For example, a tree species creates micro-environmental conditions that are habitat for epiphytic lichen species, animals, and understory plants.

The numbers of niches represent biodiversity potential, and if and how these niches are occupied by living organisms is the actual amount of biological diversity. Because any environment has a potential for some maximum expression of biological diversity that is generally limited by the existing environmental conditions, comparisons of biodiversity are only reasonable within specific ecological strata. Maximum biodiversity for any ecosystem is often realized in the absence of non-historic disturbances that sometimes result from human activities.

Biological diversity is often reported as the number of species (richness), the number or area occupied by individuals (abundance), or by indices that characterize various relationships of numbers, abundances, and distributions of species. While species richness is not per se the whole story of diversity, it is often used as an indicator of diversity because it is a simple, direct, and understandable measure of how many species are present, and is often a good indicator of stable but not static habitat conditions.

The eastern deciduous forests of the MAIA region are among the world's most floristically diverse regions, home to numerous *endemic* (common but found nowhere else) as well as rare, endangered, and threatened plant species. This diversity is the result of a relatively mild, moist climate and varying geological parent rock and topographical features. Moving from east to west, the coastal plains with their broadleaf and bottomland forests rise slightly to the clayey Piedmont section with its mixed conifer-hardwood forests, and then rise more abruptly to the rich oak–hickory forests of the western valleys and foothills of the north-south trending Blue Ridge Mountains, Allegheny Mountains, and the Cumberland Mountains. The rounded tops of these mountains are crowned with Northern firs and spruce that have been able to extend southward because of the higher elevations. The MAIA region is truly an area of high diversity at multiple scales, with a rich mix of landscapes, forest types within landscapes, tree species within forest types, and structural diversity.

### Landscape Diversity

At the landscape scale, the forests of the MAIA region are highly fragmented, with few large contiguous tracts of forests remaining. Forest fragments in the region were interspersed mainly with agriculture, urban, and other developed land uses. The watersheds closest to the Chesapeake Bay remain the most highly deforested and urbanized, while the watersheds in the western mountains are relatively contiguous.

Urbanization and fragmentation continue to be the greatest threats to the health and sustainability of the forests in the MAIA region. Increases in human population numbers and densities have resulted in the conversion of forest land to urban development and agricultural. Agriculture lands sometimes revert to forest, but are more often converted to urban land; urban land almost never reverts to forest. As the quantity of forest land is reduced, the remaining forest becomes more fragmented. The negative effects of forest fragmentation include loss of wildlife habitat, increased sedimentation and changes in the quality of aquatic systems, changes in microclimatic conditions within the forest, increased opportunities for human-induced wildfires, increased access for exotic species invasions, loss of species diversity, and species extinction.

### Forest Type Diversity

The dominant forest type was oak–hickory containing oak, hickory, red maple, yellow-poplar, other tree species that was dispersed throughout and covering 32 percent of the MAIA region (fig. 24).

There are significant concerns that oak will continue to be the dominant tree species in this region because of wildfire suppression, heavy deer browsing, and other factors that favor the regeneration of other tree species—especially red maple and tulip poplar—at the expense of oak regeneration. The second most common forest type is maple–beech–birch (composed primarily of sugar maple, red maple, American beech, yellow birch, sweet birch, black cherry, white ash, and eastern hemlock), found mostly in northern Pennsylvania, southern New York, and western mountain areas that covers 12 percent of the land. The loblolly–shortleaf pine forest type (loblolly pine, shortleaf pine, sweet gum, red maple, and red oak species) covered about 6 percent mostly in eastern Virginia and North Carolina. Other forest types were more restricted to local distributions, including other conifer types (eastern hemlock, white pine, pond pine, pitch pine); and oak–gum–cypress (swamp

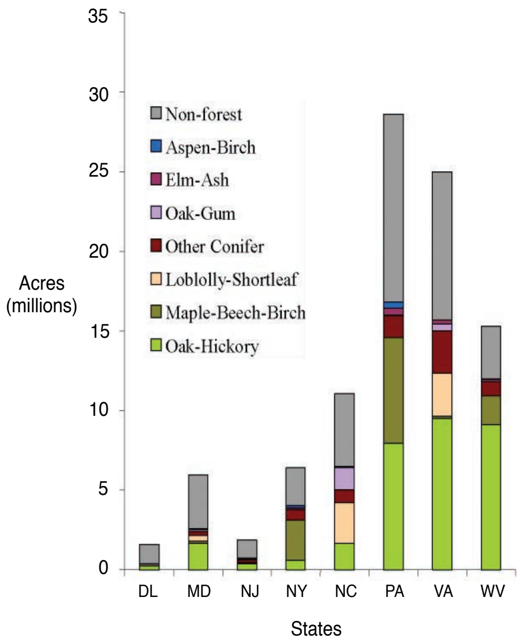


Figure 24— Forest cover type by MAIA region state.
Source: Chapter 21, Figure 107.

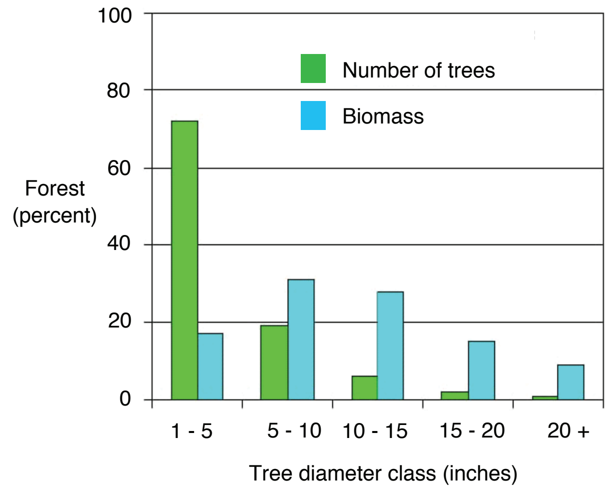


Figure 25— Distribution of numbers of trees and biomass in five size-classes in the MAIA region.
Source: Chapter 22, Figure 116.

tupelo, bald cypress, and mesic white oak species) found in wet, poorly drained areas near the Atlantic coast.

### Structural Diversity

The size and biomass distribution of trees is a measure of the structural diversity of the forests and their potential uses, as well as a measure of the resiliency of the forests to stressors. In the MAIA region, over 75 percent of the trees were found to be 1 to 5 inches in diameter, but accounted for less than 20 percent of the biomass (fig. 25).

Size distribution of trees on a biomass-basis indicated that 5 to 10 and 10 to 15 inch diameter classes accounted for about 55 percent of the total biomass, suggesting the beginning of a more stable system where the majority of the biomass is found in the mid-sized and larger trees. The largest trees in the MAIA region (greater than 20 inches in diameter) accounted for only 10 percent of the total biomass.

### Species Diversity

### Tree Genera and Species

The high diversity of forest types also entailed a high diversity of tree species. Tree species diversity—important for recreation, wildlife habitat, timber, and non-timber commodities—is influenced by climate, soils, topography, cyclic disturbances, and natural successional patterns. The diversity of tree species in the MAIA is unique, with more than 60 hardwood or softwood species found in the forests of the region, 25 of these with a relative abundance of 1 percent or more. More than 8 genera and 15 tree species were found in most of West Virginia and parts of western Pennsylvania. Red maple was the most common species in the MAIA region, accounting for 12 percent of all trees; followed by the red oak group (black oak, northern red oak, scarlet oak) at 12 percent of all trees (table 10). Loblolly pine accounted for 7 percent of all trees; most were relatively small (less than 10 inches d.b.h) and occurred on plantations managed for timber production.

Chestnut oak, white oak, yellow-poplar, and sugar maple each represented 5 or 6 percent of all trees, with white oak and yellow-poplar common in the greater-than-15 inches diameter size class. Black cherry and American beech were also in the top ten most abundant species. Sweet gum, black gum, and dogwood were common as saplings (less than 5 inches in diameter) in the understory of many forests. Even the numerous pine plantations in the Piedmont ecoregion sections of Virginia and North Carolina contained 5 to 7 genera of tree species. Tree diversity was lowest in the very

**Table 10—Relative importance (rank) of the twenty most common tree species by abundance (number of trees) in five d.b.h. size classes circa 2000. Column 1 (1 to 15+ inches d.b.h.) determined the overall rank of each species. Columns 2 to 5 are the ranks of species in other d.b.h. classes (Source: Chapter 23, Table 29)**

| | Diameter at breast height (inches) | | | | |
|---|---|---|---|---|---|
| Species | 1 - 15+ | 1 - 5 | 5 -10 | 10 -15 | 15+ |
| | species rank | | | | |
| Red maple | 1 | 1 | 1 | 2 | 3 |
| Red oaks[a] | 2 | 3 | 2 | 1 | 1 |
| White oak | 3 | 9 | 4 | 3 | 4 |
| Yellow-poplar | 4 | 10 | 7 | 5 | 2 |
| Chestnut oak | 5 | 16 | 5 | 4 | 5 |
| Loblolly pine | 6 | 8 | 3 | 6 | 6 |
| Sugar maple | 7 | 2 | 6 | 7 | 8 |
| Sweetgum | 8 | 4 | 10 | 10 | 15 |
| American beech | 9 | 7 | 14 | 12 | 7 |
| Black cherry | 10 | 11 | 13 | 9 | 9 |
| Blackgum | 11 | 5 | 12 | 11 | 10 |
| Hickory | 12 | 12 | 8 | 8 | 13 |
| Ash | 13 | 14 | 15 | 13 | 14 |
| Birch | 14 | 13 | 9 | 15 | 16 |
| Virginia pine | 15 | 17 | 11 | 14 | 20 |
| Hemlock | 16 | 18 | 16 | 16 | 12 |
| Black locust | 17 | 19 | 17 | 17 | 17 |
| White pine | 18 | 22 | 20 | 18 | 11 |
| Sourwood | 19 | 15 | 18 | 27 | 29 |
| Dogwood | 20 | 6 | 21 | 32 | 32 |

[a]Mostly black oak, northern red oak, and scarlet oak
Source: USFS Forest Inventory and Analysis program; www.fia.fs.fed.us.

wet coastal plains, which are primarily oak-gum-cypress swamps, and on the very dry ridges of the mountains which contained relatively few oak and hickory species.

## Lichen Species

Particularly sensitive to changes in air quality and climatic conditions, lichens are good indicators of air quality, stand age, disturbance, and other factors. Biologically unique—they are epiphytes that grow on tree boles, branches, rocks, etc. and get moisture and nutrients from the atmosphere—lichens are an important component of a healthy forest that can provide fixed nitrogen, food, and habitat for a variety of animals, and substrate for the germination of other epiphytic species.

The number of lichen species was highest (18 to 32 species) in the southwestern areas of the MAIA region, and lowest (2 to 12 species) in the northern half of the region, as well as most of the Coastal Plain and Piedmont regions (fig. 26).

While some of the relatively low numbers of species can be attributed to new stand development, frequently-rotated plantations, influence of sea air, etc. in coastal and Piedmont areas, the very low numbers of species in the more mature and heavily forested areas of western Pennsylvania are anomalous. Further evaluation of the stand, climatic, and atmospheric influences on lichen species in these areas is needed.

## Bird Species

Breeding Bird Survey data indicated that the number of bird species have increased significantly in many MAIA region watersheds from 1975 to 1990. In 1975 most MAIA watersheds had 8.5 to 28.6 bird species (fig. 27 a.), and in 1990 that had increased to 18.6 to 38.6 (fig. 27 b.).

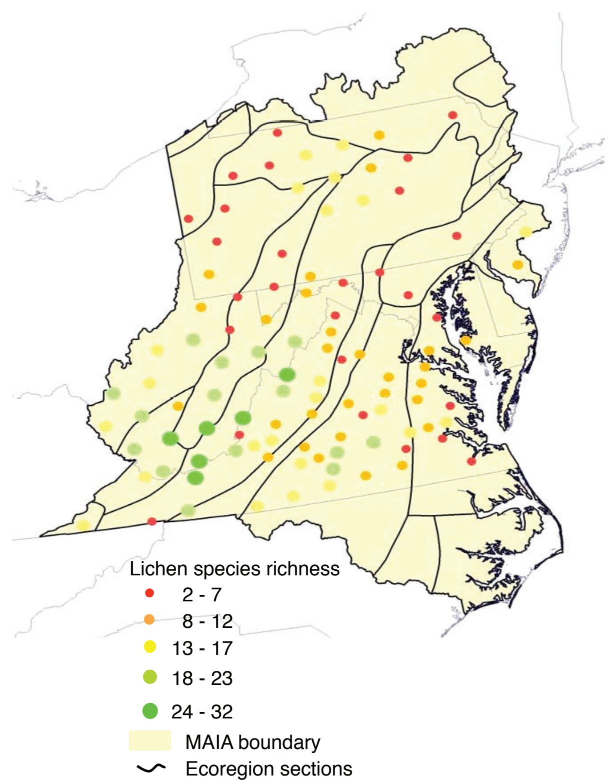


Figure 26— Lichen species richness in the MAIA region. Source: Chapter 23, Figure 118.

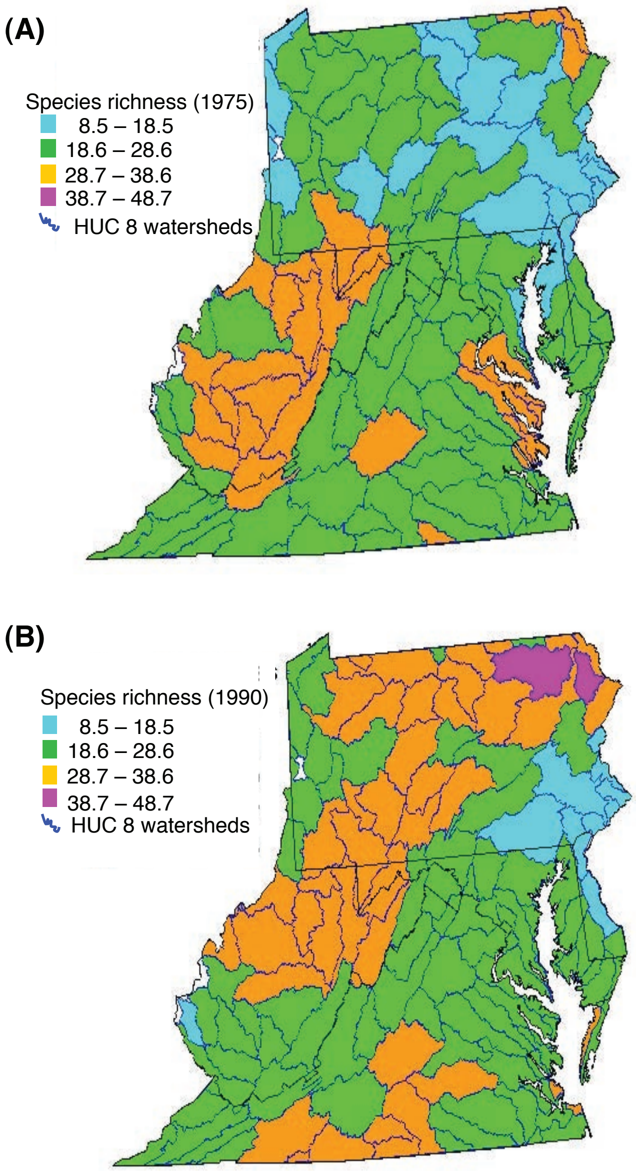


Figure 27—(a) Species richness of forest birds in HUC-8 MAIA region watersheds in 1975 based on Breeding Bird Survey data. (b) Species richness of forest birds in HUC-8 MAIA region watersheds in 1990 based on Breeding Bird Survey data. Source: Chapter 24, Figures 120 and 121.

The increased numbers of bird species were found mostly in Pennsylvania, south-central North Carolina, and parts of West Virginia. Two northeastern watersheds in Pennsylvania in 1990 averaged 38.7 to 58.9 species—more species of birds than were found anywhere in the MAIA region in 1975. We cannot say, however, whether observed increases in the number of bird species was due to increases in native bird species as a result of habitat improvement marked by the maturity of forests in these areas, or to an influx of exotic, invasive bird species.No differentiation was made between native or exotic invasive species. The lowest numbers of bird species, both in 1975 and in 1990, occurred primarily in eastern watersheds above the Chesapeake and Delaware Bays. Although species richness characterizes forest bird communities, as well as other biota, it should be emphasized that there is no threshold for what are acceptable or desirable and not acceptable or undesirable values for species richness.

*Relative richness* of bird species was used to evaluate the stability of bird communities over time, rather then just the absolute number or richness of species. This required developing a historical reference species list in 1992 that contained all bird species present on each target BBS route within distinct ecological strata based on ecological classifications detected in any past years of Breeding Bird Surveys. Evaluations were made within an 80-km radius centered on the route of interest and within the physiographic stratum in each State where the route was located. The ratio of the number of reference species to the number of same observed species from BBS surveys corresponds to relative richness, evaluated on a 0 to 1 ratio scale, where higher numbers indicated higher relative richness, which is ecologically most desirable.

Relative richness values for bird species were highest (0.75 to 0.94) indicating bird species population were most stable in watersheds near the Chesapeake Bay, and high relative richness values (0.565 to 0.75) were found in watersheds of northern Pennsylvania, and parts of northwestern West Virginia. Low relative richness ratios of 0.0 to 0.38, indicating that bird species had changed greatly, were found in watersheds of central Maryland and also in Pennsylvania where relatively large increases in species richness from 1975 to 1990 were found on BBS routes.

The BBS data and the analyses of relative species richness derived from the data did not indicate any consistent spatial patterns at survey-route scales. Some of the lowest and highest relative richness values for bird species were common on BBS routes in northern Pennsylvania where large increases in BBS data of bird species richness occurred from 1975 to 1990. Therefore there was no strong spatial relationship between increases in bird species richness from 1975 to 1990 and relative species richness evaluated in 1992.

## Long-Term Monitoring of MAIA Forests

Humans have caused major changes in forests in the MAIA region over the past three centuries, and will undoubtedly cause more in the future. Continued increases in human population with subsequent expansion of urban developments into forests will further fragment the forest landscape, reduce wildlife habitat, increase introductions of more exotic, invasive species, increase concentrations of some air pollutants, and degrade or threaten aquatic systems. Climate change effects on temperature, precipitation, and the severity of storms will add even more stress or forest ecosystems.

The value of continuous, standardized, long-term, quality-assured data sets cannot be overstated for assessing the condition and trends in forest ecosystem health and sustainability so land managers and policy makers can provide the best protection for natural resources. This type of information leads to quality assessments of current forest conditions and problems, identifies possible causal agents, and provides a sound database to monitor future directions in forest ecosystems. Continuous data sets allow researchers to identify deviations from expected patterns, to focus remedial activities on the most serious problems, and monitor the effects of those remedial actions. The continued monitoring and assessment of forest condition in the MAIA region is essential to protect an invaluable resource that provides timber, paper, furniture, recreation, esthetic values, and other resources to the millions of people living and working in this region.

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Figure 16— Average annual change in percent foliar transparency of hardwood tree for the period of record for each State by ecoregion section (colored polygons), derived from the average foliar transparency of hardwood crowns at each FHM plot (solid black dots) in each ecoregion section in 1998. The plot value was the actual value if the plot was measured in 1998, and an estimated value based on previous plot measurements otherwise. Note legend also shows annual percent change in hardwood foliar transparency for ecoregion sections outside of the MAIA region for perspective. Data collected 1991-1998 in Delaware, Maryland, New Jersey, and Virginia; in Pennsylvania in 1995 and 1998; in North Carolina in 1998.
Source: Chapter 13, Figure 53.

Figure 17—Average percent foliar transparency of softwood trees in 1998 by ecoregion section (colored polygons). The black circles show the average softwood foliar transparency at each FHM plot in 1998; the plot value is the actual value if the plot were measured in 1998 and an estimated value based on previous measurements otherwise. Data collected 1991-1998 in Delaware, Maryland, New Jersey, and Virginia; in Pennsylvania in 1995 and 1998; in North Carolina in 1998.
Source: Chapter 13, Figure 56.

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Figure 26— Lichen species richness in the MAIA region.
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Figure 27—(a) Species richness of forest birds in HUC-8 MAIA region watersheds in 1975 based on Breeding Bird Survey data. (b) Species richness of forest birds in HUC-8 MAIA region watersheds in 1990 based on Breeding Bird Survey data.
Source: Chapter 24, Figures 120 and 121.

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**Stolte, Kenneth W**. 2012. State of mid-atlantic region forests in 2000-Summary Report. Gen. Tech. Rep. SRS–163. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 37 p.

Wet and warm climate, mountainous topography, and deep rich soils produced one of the most magnificent and diverse temperate forests in the world. In 1650 the Mid-Atlantic forests covered 95 percent of the region, but were greatly reduced in 1900 by extensive tree harvesting, and conversion to farms and pastures. Settlement of forests also led to severe wildfires, soil erosion, and destruction of wildlife. Recovery began in the early 1900s, and later improvements in agricultural allowed millions of acres to return to forest cover. Suppression of catastrophic wildfires reduced flooding and watershed degradation, and wildlife management returned native animal and fish populations. Forest management improvements led again to productive and diverse forests in more mature stages of development. By the end of the 20th century, the Mid-Atlantic forests covered 61 percent of the land area and produced numerous products that brought social and economic benefits to people. Continuing pressures from urbanization and fragmentation; selective species harvests; air pollution; exotic invasive species; wildlife habitat loss; historic fire regime changes; stream degradation; and climate change still affect and threaten these forests, and require enlightened management and policy decisions to ensure sustainability of healthy, diverse, and productive forests.

**Keywords:** forest health, forest economics, indicators, stressors, sustainability, Mid-Atlantic forests, Montreal Process Criteria and Indicators