McCullough's account of the unique town forest movement in New England and Massachusetts. The concluding chapter, "The Massachusetts Forest Today," by former Massachusetts natural resources commissioner and environmental secretary Charles H. W. Foster, indicates how the lessons of history can be applied usefully to shape future programs and policies.

An Ecological History of Massachusetts Forests

JOHN F. O'KEEFE AND DAVID R. FOSTER

THE FORESTS of Massachusetts present a history of almost continual change. However, the scale, rates, and causes of these changes have varied dramatically through time. The relative importance of human disturbance compared to natural disturbance has steadily increased — gradually at first, as aboriginal activity expanded and included agriculture, and then dramatically since European settlement. Moreover, the variety, frequency, and extent of human disturbance have generally increased through time and can be expected to continue increasing and changing into the future.

Any effective forest-management policy to protect the health, values, and resources of Massachusetts forests must develop from an understanding and consideration of this history. It is critical that conservation, forestry, wildlife management — in fact, all environmental decision-making — begin with knowledge and appreciation of the history and dynamic nature of our landscape. Without these, any plan will almost certainly produce surprises, if not failure. The forests have reclaimed abandoned farmland and now cover nearly two-thirds of Massachusetts. As our population expands onto this land, suburban forest owners, largely unaware of the past changes in our forests and only slightly more informed of the current ones, must consider the history and dynamics of these forests in their backyards. We are blessed with a landscape and climate that are ideally suited for growing trees and forests, but without an understanding of the past we may unwittingly lose many of the values these forests can provide.

SHOULD OUR HISTORY begin with the arrival of European settlers? Probably not. The forests they found had long been influenced by aboriginal activities. For millennia our forests had been evolving into the landscape that greeted the settlers. One reasonable start for our forests' history is the end of the last glacial period, more than 13,000 years ago.

This chapter is composed of five sections. The first describes the dramatic changes following the melting of the glaciers as our present forests were developing. The second provides a view of the natural factors that help determine the distribution of different types of forest. The third examines the types of disturbance, both natural and human, that shaped the forests prior to European settlement. The fourth describes the amazing changes that our forests have undergone since European settlement as they were cleared for agriculture and have subsequently regrown on abandoned farmland. The final section reviews the current state of Massachusetts forests and the pressures and stresses they are under, and suggests some lessons from their past that might help direct their future management. Table 1 provides a chronology of some major events in our forests' history over the last 15,000 years.

The authors of this chapter are both ecologists on the staff of the Harvard Forest, a research and educational department of Harvard University located in Petersham, Massachusetts. David Foster is director of the Harvard Forest and John O'Keefe is coordinator of the Fisher

Table 1. Approximate chronology for important events in the development of Massachusetts forests.

Approximate Years Before Present (B.P.)	Landscape Condition/Event
> 13,000	Glacial ice
13,000	Tundra
11,500	Spruce woodland and forest
10,000	Human arrival
9,500	Pine forest
8,000	Mixed deciduous forest
5,000	Hemlock decline
3,000	Arrival of chestnut trees
1,000	Native American agriculture
250–350	European settlement
150	Peak of agricultural clearing
85	Chestnut blight
60	1938 hurricane

Museum, a small museum devoted to understanding the land-use history, ecology, and management of New England's forests. Scientists at Harvard Forest have intensively studied the forests of central Massachusetts since the turn of the century and amassed an unparalleled database from these studies. The authors have drawn heavily on this database for information and illustrations, which is the reason for the numerous references to Petersham and north-central Massachusetts in their work and examples. However, they have noted when other areas may not fit these examples and present the story of all Massachusetts forests.

I. POSTGLACIAL FOREST DYNAMICS

At the peak of the last glaciation, over 15,000 years ago, most of present-day Massachusetts was covered by ice up to a mile thick. Cape Cod and the offshore islands, Nantucket, Martha's Vineyard, and the Elizabeth Islands consist largely of what geologists call moraines, piles of debris accumulated at the front of the advancing ice sheet and left behind when the glaciers finally melted. The advancing glaciers not only smoothed and shaped the landscape by scraping and plucking the bedrock as they advanced, they also left behind a layer of ground-up rock, or *till*, which has developed into our present soil. As the glaciers melted, the tremendous volume of water produced seasonal streams that carried and sorted much of this material and deposited sands and gravels wherever they slowed (Strahler 1966). The soils of Massachusetts are a product of this massive natural engineering, with the subsequent addition of organic material from the vegetation that covered the landscape. Along major rivers fine silt was deposited when the rivers overflowed their banks in spring; in some depressions a surplus of moisture allowed thick layers of peat or muck to develop. The resulting pattern of soil types has strongly influenced the types of trees and forests growing in different locations.

Of course, as the glaciers melted, there were no forests in Massachusetts. The climate change that allowed the glaciers to develop limited the modern tree species of New England to favorable locations, or *refugia*, south of the glacial zone, presumably scattered across the southern Appalachians and the eastern coastal plain. The huge quantities of water trapped on land as glacial ice had once been seawater;

consequently, sea level was several hundred feet lower than at present. This exposed vast areas of continental shelf off the present-day East Coast for refugia as well. The forests in these various refugia contained species mixtures unlike any we are familiar with today. As the climate warmed and the glaciers melted the trees began their migration north. The rate of migration of each species was determined by its seed dispersal and its climatic tolerance.

We are fortunate to have a record of the vegetation change following the glacial period in the form of pollen preserved in sediments at the bottom of lakes and ponds and below many wetlands. Each year pollen from plants growing in an area is carried on the wind. When it lands on the water of a pond or lake, it sinks to the bottom and along with other wind-borne material is incorporated into the sediments. These sediments form a layered time sequence, with the oldest at the bottom, which scientists can core into and recover as a thin cylinder or core of mud. The different layers in the core can be dated using radioisotopes. Pollen is extremely resistant to decay and because the pollen of different plants can be identified (generally to genus and in some cases to species), the presence and relative abundance of different species enables paleoecologists to reconstruct the major vegetation changes at a site.

The Harvard Forest Black Gum Swamp pollen diagram (Figure 1) shows vegetation changes through time that are typical of those from sites across Massachusetts. As the glaciers melted and the climate warmed, a period of tundra was followed by boreal (northern conifer) forest, then pine forest with rapidly increasing amounts of several deciduous species (oak, birch, beech) by 8,000 years ago. Although mixed deciduous forests have been dominant for about the last 8,000 years, they have changed continually through time, and these changes can tell us much. Different species have behaved quite independently, presumably migrating to Massachusetts from different locations at different rates, each species responding in its unique fashion to combinations of climatic, soil, biotic, and historical factors. The resulting forest communities constantly changed through time. The major influences on these changes are long-term climate change, migration rates of individual species, and natural disturbance processes.

Population dynamics of selected species can help us understand these processes. Hemlock increased rapidly in importance after its arrival about 9,000 years ago. A little less than 5,000 years ago, it

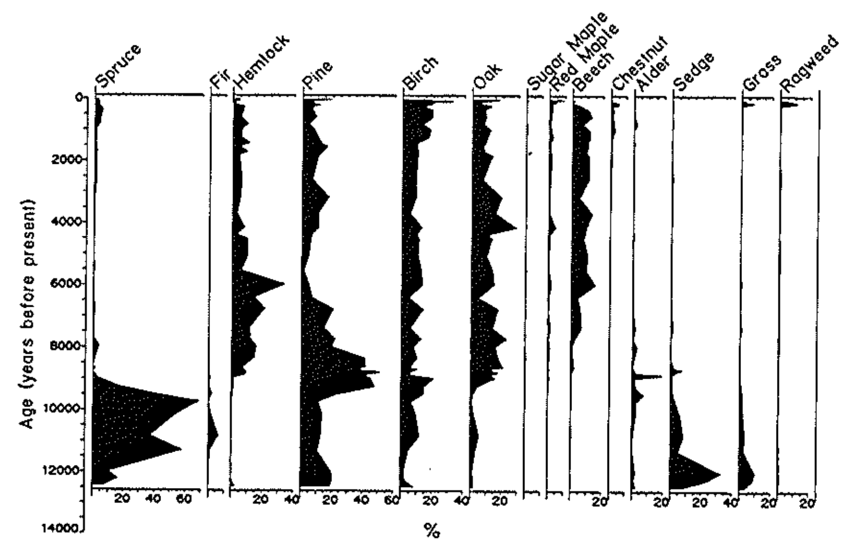


Figure 1. Pollen diagram from the Black Gum Swamp at Harvard Forest in central Massachusetts depicting the major changes in the vegetation over the past 12,500 years. Tundra communities (sedge, grass) were replaced by boreal forest dominated by spruce until approximately 9200 B.P. (before present), when pine and then hardwood tree species became important. Changes in the relative abundance of species resulted from climate change, species migrations, disease (hemlock decline at about 5000 B.P.) and fire until 250–300 years B.P., when European settlement resulted in major deforestation and the increase in agricultural weeds (ragweed), grass, and early successional species. Modified from Foster and Zebryk (1993).

decreased dramatically in a very short time, then slowly recovered. This sudden decline in hemlock is seen in pollen records throughout the Northeast and is attributed to a severe pathogen (insect or disease) outbreak, which dramatically decreased hemlock populations for nearly 1,000 years.

Regional pollen analyses indicate that the period from 8,000 to 5,000 years ago was most likely somewhat milder than the last 4,000 years have been (Davis 1958). During the warm period many common tree species migrated into Massachusetts and some species expanded their ranges well north of their current limits. Fire frequency, shown by charcoal in sediment cores, was also greater at a number of sites (Patterson and Backman 1988). A more recent cooling probably produced the increase in spruce pollen over the last 2,000 to 3,000 years. Yet these changes and forest community dynamics were complex: while spruce, a northern species, increased — evidently in response to gradual cooling — chestnut, a southern species, was also migrating north across Massachusetts. In fact, chestnut is the most recent arrival in the pollen record, not appearing until about 3,000 years ago, much later than the other important deciduous species that occur in the region today.

II. NATURAL ENVIRONMENT

The development and distribution of forest types across Massachusetts during the presettlement period were controlled by the geographic pattern of the landscape, or physiography, the underlying geology, and the patterns of various types of disturbances such as windstorm and fire, which are all interrelated. Massachusetts, excluding Cape Cod, is roughly rectangular, 125 miles (200 km) east to west and 50 miles (80 km) north to south. Today we receive approximately 40 inches (100 cm) of precipitation annually, distributed fairly evenly throughout the year. With a mean annual temperature near 50°F, ranging from a mean of several degrees below freezing in January to a mean of about 70°F in July, our climate today is very well suited for trees and apparently has been for the last 10,000 years.

Within this relatively small compact area, Massachusetts contains six broad physiographic regions: the coastal lowlands, the central uplands, the Connecticut River valley, the Berkshire Mountains, the Berkshire valley, and the Taconic Mountains (Figure 2). The geologic substrate varies across the state. Except for parts of the Connecticut valley, the Taconic Mountains, and the Berkshire valley the soil is generally acidic and fairly nutrient-poor. The soils are generally shallow with patches of exposed bedrock. Elevation generally increases from east to west, reaching a maximum at Mount Greylock (3,487 feet [1,060 m]) in the Berkshires.

As mentioned, these physiographic and geological conditions interact with climate to produce vegetation zones sometimes referred to as ecoregions. Figure 3 shows the Massachusetts portion of a natural vegetation zone map of New England (Westveld 1956). Within Massachusetts these zones are largely determined by climate, which is principally controlled by elevation except in areas with close proximity to the moderating influence of the ocean. Southeastern Massachusetts, all of

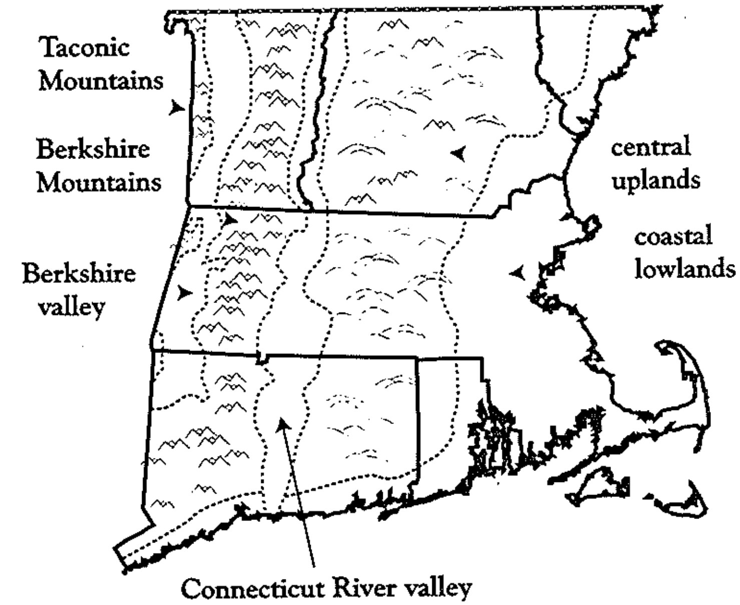


Figure 2. Map of southern New England depicting the major physiographic regions. From east to west they are coastal lowlands, central uplands, Connecticut River valley, Berkshire Mountains, Berkshire valley, and Taconic Mountains. Modified from Wright (1933) and Jorgensen (1977).

Cape Cod, and the offshore islands fall within the pitch pine-oak zone. This vegetation type, occurring on sandy and gravelly soils laid down as glacial moraines or outwash deposits, is characterized by drought-tolerant and fire-adapted species including pitch pine, scrub oak, and huckleberry. This type also occurs on scattered outwash deposits in inland Massachusetts. The remainder of the coastal lowlands, southern Worcester county, and the southern Connecticut River valley fall within the central hardwood-hemlock-white pine zone. This vegetation type represents the northern extension of the oak-hickory dominated forests of the central Appalachians and the Middle Atlantic states.

Generally north and west of the central hardwood zone we find the transition hardwood zone. This zone also extends up the major river valleys in the western part of the state. The transition hardwood zone is characterized by increasing amounts of more northern species such as yellow birch, black birch, sugar maple, and beech; less oak (especially white oak); and the general occurrence of paper birch on heavily disturbed sites. The higher elevations in the Berkshire and Taconic

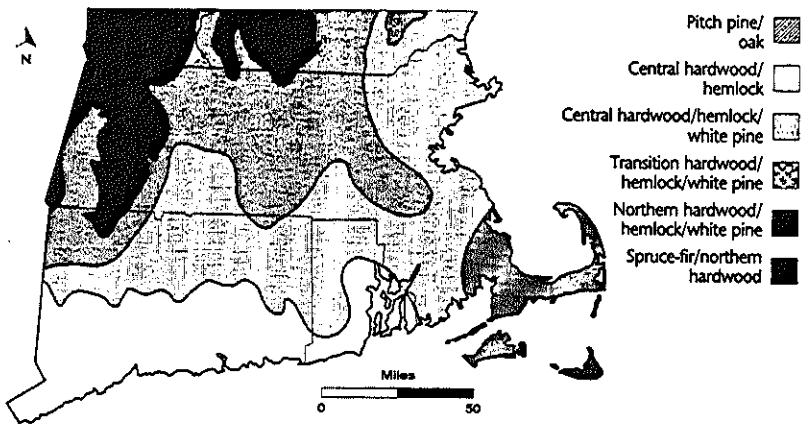


Figure 3. The major forest vegetation zones in southern New England. Glacial sandy deposits forming the area of Cape Cod and extreme southeastern Massachusetts support a dry forest of pitch pine and scrub oak species. Central hardwood forest, a northern extension of the oak-hickory forest type, covers most of the coastal lowland. Transition hardwood forest dominates the central uplands and much of the Connecticut River and Berkshire valleys with northern hardwood forest on the higher elevations in the Berkshires and Taconics and spruce-fir forest on the highest elevations. Modified from Westveld (1956).

mountains and in extreme northern Worcester County fall within the northern hardwood and spruce-fir zones. The spruce-fir zone is restricted to the highest elevations, generally above 2,000 feet, and has red spruce as the dominant conifer, while the northern hardwood zone occurs just below the spruce-fir zone and has hemlock and white pine as its dominant conifers. Both zones have hardwood mixtures dominated by sugar maple, yellow birch, beech, and red maple.

III. NATURAL AND PRESETTLEMENT DISTURBANCE

Natural Disturbance

These natural vegetation zones represent idealized conditions as they have developed over the last two millennia or so, as forests responded to existing physiographic, geologic, climatic, and soil conditions. What major disturbance processes have been active during this time frame? The major natural disturbances affecting Massachusetts forests include windstorm, pathogens (insect and diseases), and fire. Although direct

soil evidence of the uprooting of trees may persist nearly 1,000 years (Stephens 1955; Lyford and MacClean 1966), over millennia storm frequency and pattern have undoubtedly varied with changing climatic conditions. Nevertheless, trends can be estimated from observations over the past few hundred years. Two different types of windstorms cause significant damage to Massachusetts forests: tropical storms or hurricanes, and downbursts or microbursts — sudden, straight-line winds — often from the northwest, associated with severe thunderstorms and occasionally accompanied by tornadoes. Downburst winds are probably the dominant wind disturbance in the Berkshires and western Massachusetts. They continue east across central Massachusetts and become somewhat less important in the more stable areas under maritime winds near the coast. While commonly rather local, the potential destructiveness of these events was demonstrated in July 1995, when hundreds of thousands of acres of forest from the Adirondacks of New York into western Massachusetts were severely damaged by an extremely large and long-lived downburst front (Jenkins 1995).

Tropical storms represent the most important wind disturbance in central and eastern Massachusetts. Historical evidence indicates that hurricanes may affect central and eastern areas approximately every 100 years, with the Cape and islands affected somewhat more often (Figure 4). These large, counterclockwise-rotating storms have the strongest winds on their easterly side. Catastrophic hurricanes may be generally restricted to those with tracks paralleling the 1938 and 1815 storms, which produced the greatest damage in areas receiving winds from the south and east, probably typical for severe hurricanes in Massachusetts (Foster and Boose 1992). Hillsides facing south and east would receive repeated hurricane damage, while steep north and west slopes would tend to be protected and may have developed a different vegetation. Western exposures and ridges would be prone to selective damage from the more patchily distributed microburst winds associated with severe thunderstorms.

The only strong evidence for a pathogenic disturbance in the paleoecological record is the widespread hemlock decline nearly 5,000 years ago, mentioned previously (Figure 1). The rapidity and extent of this decline, not associated with declines in other species or identifiable climatic change, points to a species-specific pathogen as the cause. Hemlock remained at low population levels for nearly 1,000 years. It

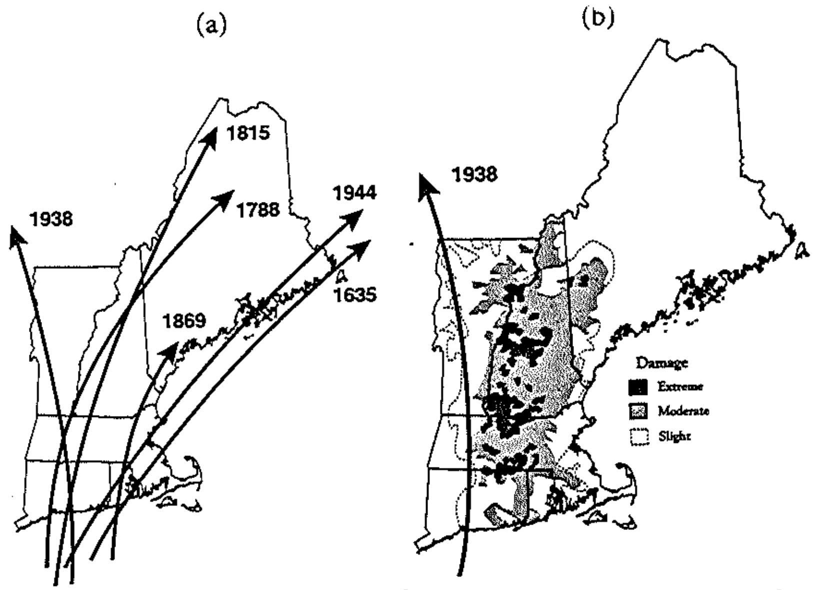


Figure 4. (a) Paths of the major hurricanes that have impacted New England from 1600 to present and (b) the damage (indicated in three categories) inflicted on forests in the region by the 1938 hurricane. Approximately 3 billion board feet of timber were windthrown by the storm, more than 600 lives were lost, and damage costs exceeded $100 million. Modified from Smith (1946) and Foster (1988).

gradually approached its predisturbance abundance at many sites between 1,000 and 1,500 years later (Allison et al. 1986). Forest response to this event differed across the region. Hemlock never fully regained its former importance at some sites, presumably because of competition with recently immigrating species or slight climatic changes over the interim. Of course, this event offers many comparisons with the human-transported pathogens (gypsy moth, chestnut blight, hemlock woolly adelgid) to be discussed later, with which our forests are coping today.

Like windstorms, fire probably differed significantly in its impact across Massachusetts as a result of differences in climate, fuel abundance (vegetation type), and ignition sources (lightning and aboriginal populations). When we look at the impacts of fire, we encounter the first strong evidence of human influence on Massachusetts forests. Charcoal evidence from sediment cores indicates that fires were less

frequent and significantly smaller in the Berkshires than in southeastern Massachusetts and on Cape Cod (Patterson and Sassaman 1988). The droughty, sandy soils of the southeastern area supported a much more fire-adapted vegetation largely dominated by pitch pine, scrub oak, and other oaks and huckleberry. Pitch pine, like all conifers, contains resins in its needles that make it much more flammable than our broadleaf, deciduous trees. Huckleberry, although a broadleaf, deciduous species, also contains resins in its leaves and therefore provides a very flammable understory. All the oaks, especially scrub oak, are prolific sprouters following injury. Pitch pine is unique among Massachusetts' native conifers in possessing dormant buds beneath the bark and near the base of its trunk that enable the tree to sprout and survive if the main stem is severely damaged by fire. Moreover, the cones of pitch pine tend to be *serotinous*, which means they may remain closed with seed inside until the heat from a fire triggers an opening mechanism to release the seeds onto the recently burned landscape. Although pitch pines in Massachusetts rarely exhibit this behavior today, it is commonly observed in pitch pines in the frequently burned New Jersey pinelands.

The northern hardwood species — sugar maple, beech, and yellow birch — while capable of sprouting, tend to have thinner bark that provides less protection from understory fires. Hemlock, a major associate in the northern hardwood forest, is also thin-barked as well as slow-growing, long-lived, and incapable of sprouting. Therefore, where these species were dominant, we can conclude that fires could not have been frequent or severe. Moreover, during the growing season, broadleaf foliage normally contains enough water to be nonflammable. This moisture tends to limit the fire season in our broadleaf forests to spring and fall, when the fallen dry leaves will burn in surface or brush fires. In fact, the combination of these factors led some to nickname the northern hardwood forest "asbestos forests."

Aboriginal Impacts

There is considerable debate regarding the extent of aboriginal impact across the broad-scale forest landscape. American Indian populations migrated into Massachusetts shortly after the trees, some 10,000 years ago, but their populations remained quite low until 4,000 or 5,000 years ago. Some researchers speculate that the hemlock decline about this time, and subsequent increase in mast species (*mast* means hard food such as nuts that accumulate on the forest floor) such as oak and hickory, which produce abundant large nuts edible by both wildlife and humans, may have contributed to the increase in aboriginal populations (Mulholland, personal communication).

Archaeological evidence indicates that aboriginal populations — like the incidence of fires — were more numerous in the eastern than in the western part of the state, with settlements also along the major river basins, as shown in Figure 5 (Patterson and Sassaman 1988). There is little evidence that these populations cleared extensive areas for agriculture. Rather, they most likely created a patchwork of cleared areas, abandoned fields, and village sites in a matrix of intact forest. Population density and presumably human impact on the forest gradually decreased moving away from the coast (Whitney 1994), from a high of up to 50 people per square mile on Nantucket to 4 to 10 per square mile in inland eastern and southeastern Massachusetts and the Con-

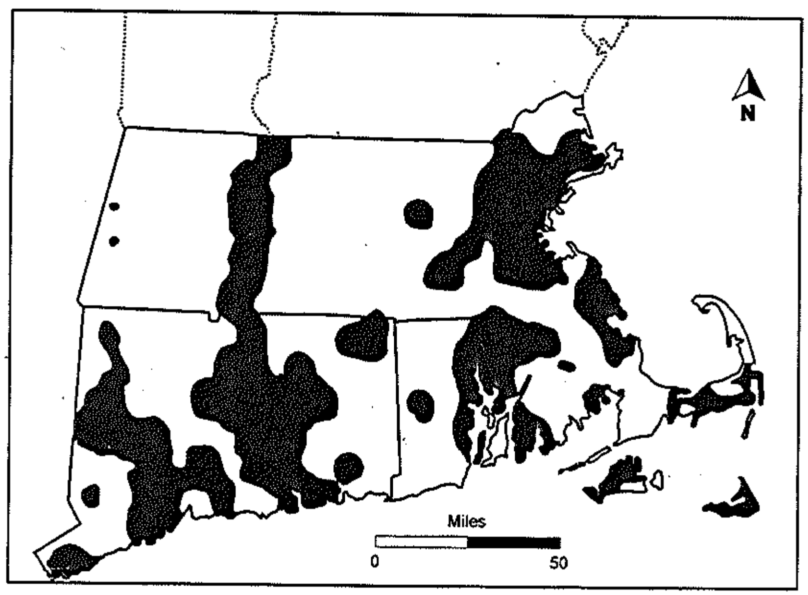


Figure 5. Areas of concentrated aboriginal populations (black) in southern New England during the Late Woodland period (A.D. 1000–1600) preceding European settlement. Populations were concentrated along major river valleys, the coast, and the larger islands of Nantucket and Martha's Vineyard and were low across broad upland areas. Modified from Patterson and Sassaman (1988).

necticut River valley, with probably no permanent settlements in the upland Berkshires.

It is interesting to note that the pattern of high population density (Figure 5) tends to follow the distribution of the central hardwood and pitch pine–scrub oak forest zones on Westveld's map (Figure 3). These would be the forest types most suitable to burning. Although there is still extensive debate over the frequency, extent, and broad-scale impacts of aboriginal burning (Cronon 1983; Whitney 1994), there is general agreement that these populations did burn to create fields and remove and rejuvenate understory browse for deer and other animals they hunted. This burning was probably largely restricted to dry areas with vegetation adapted to fire, but undoubtedly it served to maintain these conditions by eliminating regeneration of fire-sensitive species. In dry periods, human-set fires may even have altered the distribution of fire-sensitive species. Early reports of aboriginal burning indicate that most fires were set in the spring or fall and burned primarily the new litter and other small material that had recently collected on the forest floor. Undoubtedly feedback mechanisms between forest types and aboriginal practices reinforced the distribution of both. Such tight links were most important near the coast and inland up to the "tension zone," where the central hardwood forest met the transition hardwood forest.

We have traced how the postglacial landscape interacted with migrating species and different disturbance patterns to create the pre-European forests of Massachusetts. Several important lessons emerge from this review:

- Both the environment and the forest communities have a dynamic history without long-term equilibrium.
- When forests are seriously disturbed, restructuring can take a long time.
- Most pre-European disturbances were infrequent and distributed unevenly across the landscape.
- The forest communities that the Europeans encountered had been in place a relatively short time, evolving under dynamic conditions (Foster 1995).

What has been the fate of our forests since the arrival of Europeans?

IV. POST-EUROPEAN DYNAMICS

The Colonial Period

European settlement in Massachusetts spread inland from the coast at uneven rates. Essex, Suffolk, Norfolk, Plymouth, and Bristol counties were largely settled by 1675, as was the Connecticut River valley, with settlers moving northward from settlements in the Springfield area that dated from the 1630s. Concentrated in the coastal lowlands and major river valleys, this early settlement pattern closely overlapped the areas where aboriginal practices had most affected the forests. Settlement then spread to much of Middlesex and Worcester counties in the late seventeenth and early eighteenth centuries and expanded into the foothills of the Connecticut River valley during the same period. In 1725 Massachusetts began using land grants to pay off debts, especially for military service (Clark 1983), which encouraged the settlement of the central upland areas. The last areas to be settled, from the second half of the eighteenth century into the beginning of the nineteenth century (Figure 6), were the northern portions of Worcester County and the uplands of the Berkshires.

Initially, clearing occurred quite slowly for several reasons, including lack of markets for excess production and a town organization based on the European model of a centralized settlement and common field system (Whitney 1994, Foster 1995). More than 100 years after its settlement in 1635, Concord was still more than 50 percent forested. This rate of about 0.4 percent deforestation per year was typical of towns in the seventeenth century (Whitney 1994). A shift to a town pattern of dispersed settlement and individual ownership of private land, with all land in the township distributed, led to much more rapid deforestation toward the middle of the eighteenth century. Rates of 0.8 percent to 1.0 percent per year were common in both older towns like Concord and new ones like Petersham in the second half of the eighteenth century (Figure 7). This clearing coincided with a shift toward a market economy, partly driven by a developing beef trade with the West Indies. Animals were a suitable crop on remote hilltown farms during this period because they could be walked to market on the rudimentary roads that precluded the long-distance transport of most products. The difficulty of transport also partly explains the methods most commonly used to clear the forest, girdling

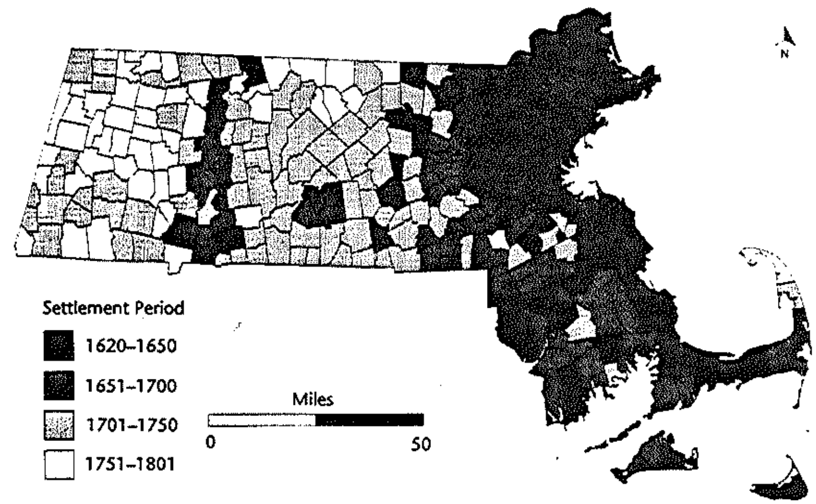


Figure 6. European settlement patterns of Massachusetts showing early settlements along the coast and in the southern Connecticut River valley, slowly expanding west and north respectively through the seventeenth century and then more quickly filling the central area during the first half of the eighteenth century. The last areas to be settled were the Berkshires and the north central tier of towns. In a few cases, "late" settlement may reflect town subdivision dates.

and leaving the dead trees in place to fall apart slowly, or cutting the trees and burning them (Whitney 1994). Except where water transport was available, trees were valuable only locally as lumber or firewood. Potash, a relatively more compact and transportable product, was probably the major marketable product from the trees of these early farms.

Pasture suited the landscape of most of Massachusetts quite well. The rockiness of most soils made clearing land for tillage a long and backbreaking chore. It has been said that it took two generations to clear upland farms for plowing, the first to remove the trees and the second to remove the stones. The massive stone walls surrounding abandoned fields across the state attest to the effort required by the second endeavor. And yet the great number of rocks scattered throughout the remaining pastures and second growth woods suggest that the majority of the landscape was never tilled, but rather grazed or at most mowed. The principal exceptions of course were the major river valleys where postglacial alluvial deposits provided excellent tillage after the

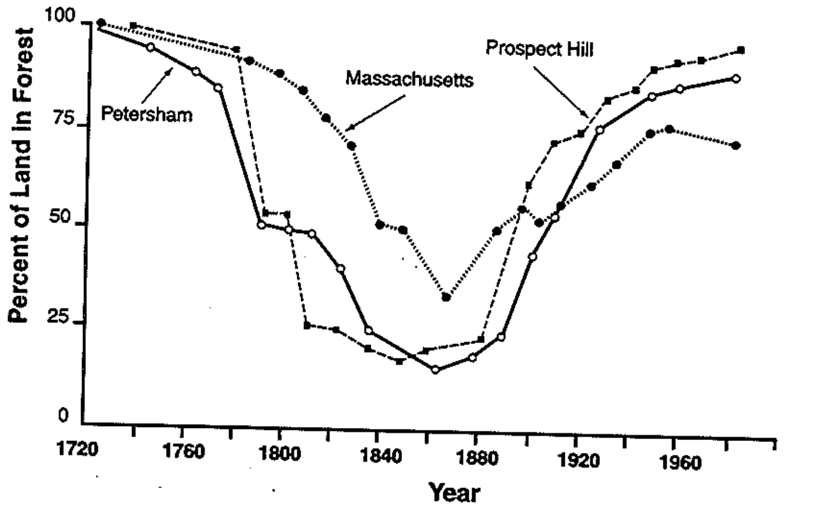


Figure 7. Changes in the percentage of the land area covered by forest during the historical period in the state of Massachusetts, the town of Petersham, and the Prospect Hill tract of the Harvard Forest. Information is derived from the following sources: Dickson and McAfee (1988), MacConnell (1975), Rane (1908), and Baldwin (1942) for Massachusetts; Raup and Carlson (1941), MacConnell and Niedzwiedz (1974), Cook (1917), and Rane (1908) for Petersham; and from Foster (1992) and Spurr (1950) for Prospect Hill.

mere removal of the trees. These areas are most notable for their lack of stone walls.

In upland areas, hilltops were often selected for village centers and initial clearing because they appeared to offer the best agricultural soils, with good drainage and relatively fewer stones. Except for the broad river valleys, inland lowlands often offered poor drainage and a shorter growing season. Land quality and therefore potential use was commonly evaluated on the basis of topography and forest vegetation; see Figure 8 (Whitney 1994, Foster 1995). Initially farmers might clear six to eight acres over the course of several years. When tilled this initial clearing could support a typical family of five to seven (Whitney 1994). During this period low-intensity agriculture combined with artisanship was the dominant employment and economic base of rural Massachusetts. Few individuals provided for all their own needs through their own labor, but through cooperation and exchange townships could be

largely self-sufficient. Each town supported a range of artisans, shops, mills, and tanneries. Roads provided internal circulation but relatively poor access to external markets. At the same time, coastal communities were developing extensive fishing and shipping industries utilizing local forests for shipbuilding materials and export products. By the mid-1700s Salem was the most prosperous port in the country and a center of worldwide trade.

Agricultural Period

The late 1700s through the first half of the nineteenth century saw a major transformation of the Massachusetts economy, social structure, and landscape (Pabst 1941; Merchant 1989; Baker and Izard 1987). The rural economy shifted from home production and local consumption to market-oriented intensive agriculture. Transportation was greatly improved through construction and development of roads, canals, and railroads. Farmers responded to the expanding markets by clearing more forested land and draining wetlands, both often on marginal agricultural sites. Pasture remained the primary land use, as beef and wool were dominant products until canal and rail connections with the west and relaxation of wool tariffs in the 1830s–40s reduced their profitability (Pabst 1941). Most farm families also engaged in home production of some sort (shoes, hats, clothes), and many also earned some income from mills or tanneries. Local industry thrived, and most hill towns reached their agricultural and commercial, as well as population, peaks during this period (Foster 1995). However, this period also represented the start of regional industrial concentration, a factor that together with the developing national transportation network and westward expansion signaled the eventual decline of New England agriculture.

Many towns literally moved downhill, from being ridgetop agricultural villages to being riverside industrial towns. Hill towns without significant water-power resources began a gradual decline. Factories, which began small, employing local residents, often grew tremendously, attracted many immigrants, and produced quantities of textiles, wooden products and tools (Botts 1934). The developing railroad network, which followed the same watercourses that the factories used for power, transported raw materials and finished products to and from the factories. The new roads and railroads allowed many nonperishable

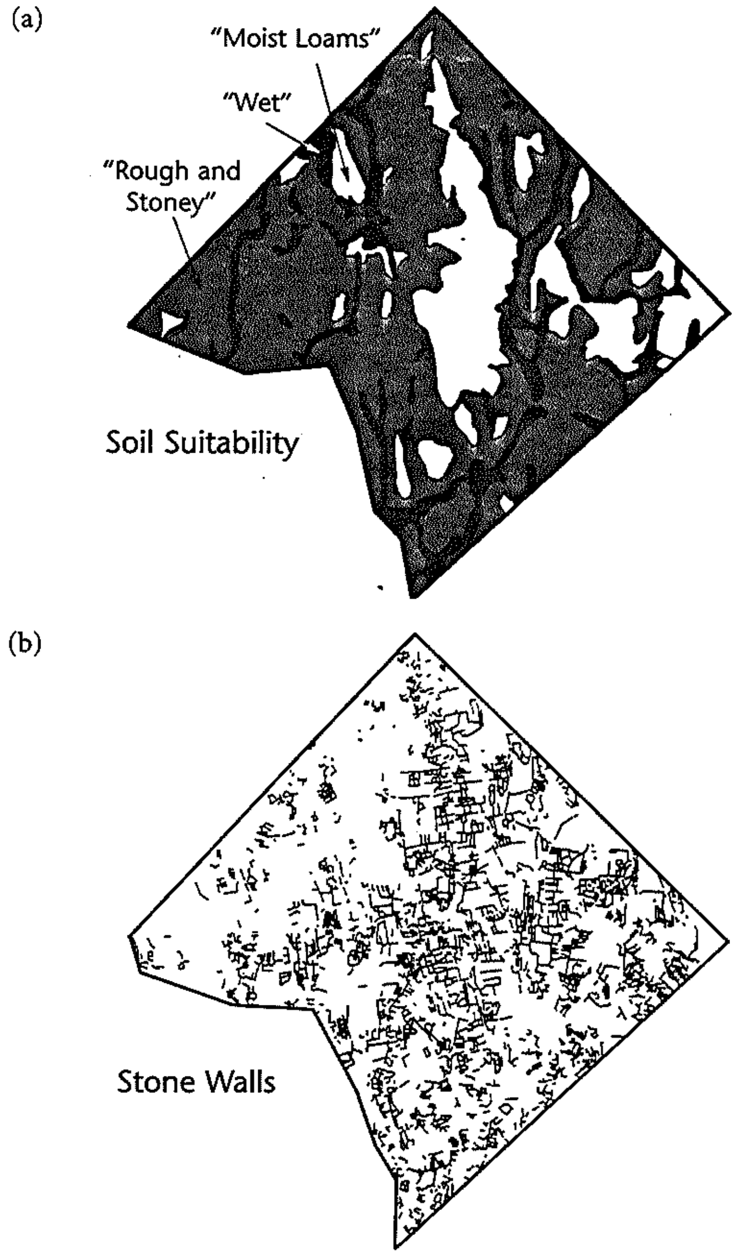
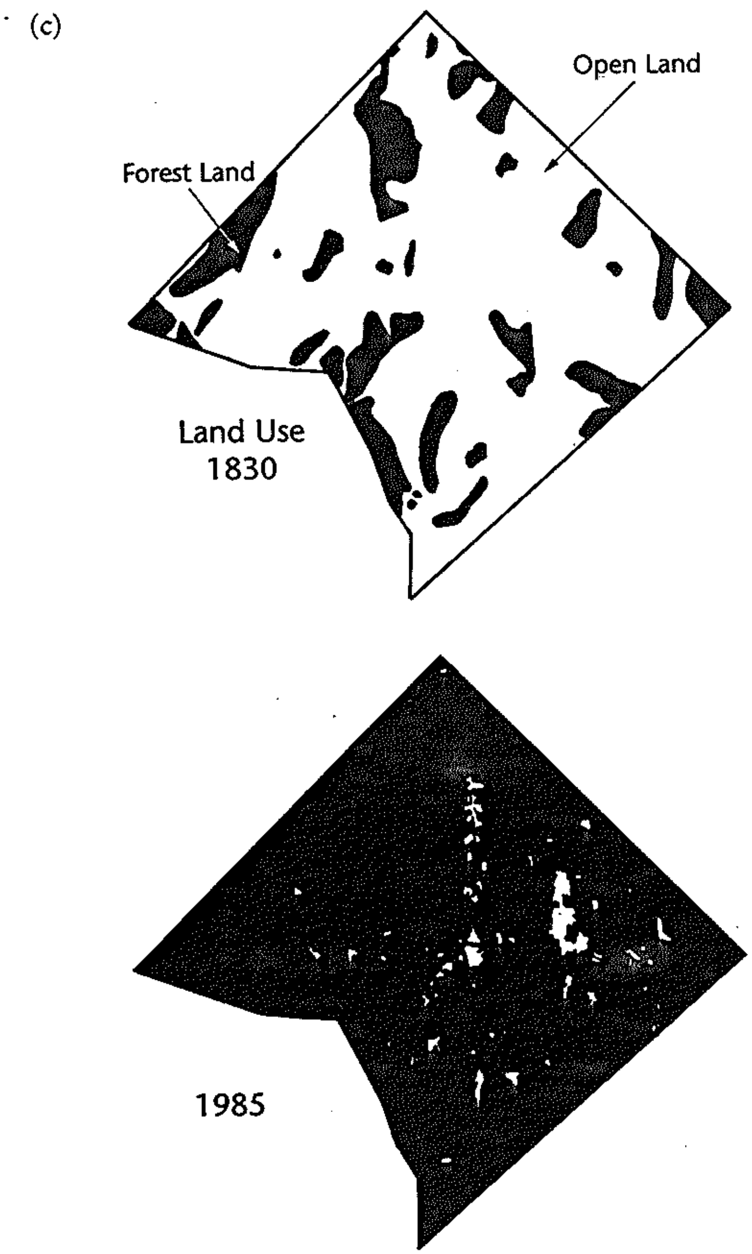


Figure 8. The township of Petersham, Massachusetts. (a) Soil suitability, (b) stonewalls and (c) forest cover from the periods 1830 and 1985 are depicted.



Stone walls and agricultural land are concentrated in areas of more productive soil. Maps are compiled from the atlas of Worcester County (1830, unpublished) and analysis of aerial photographs for 1985.

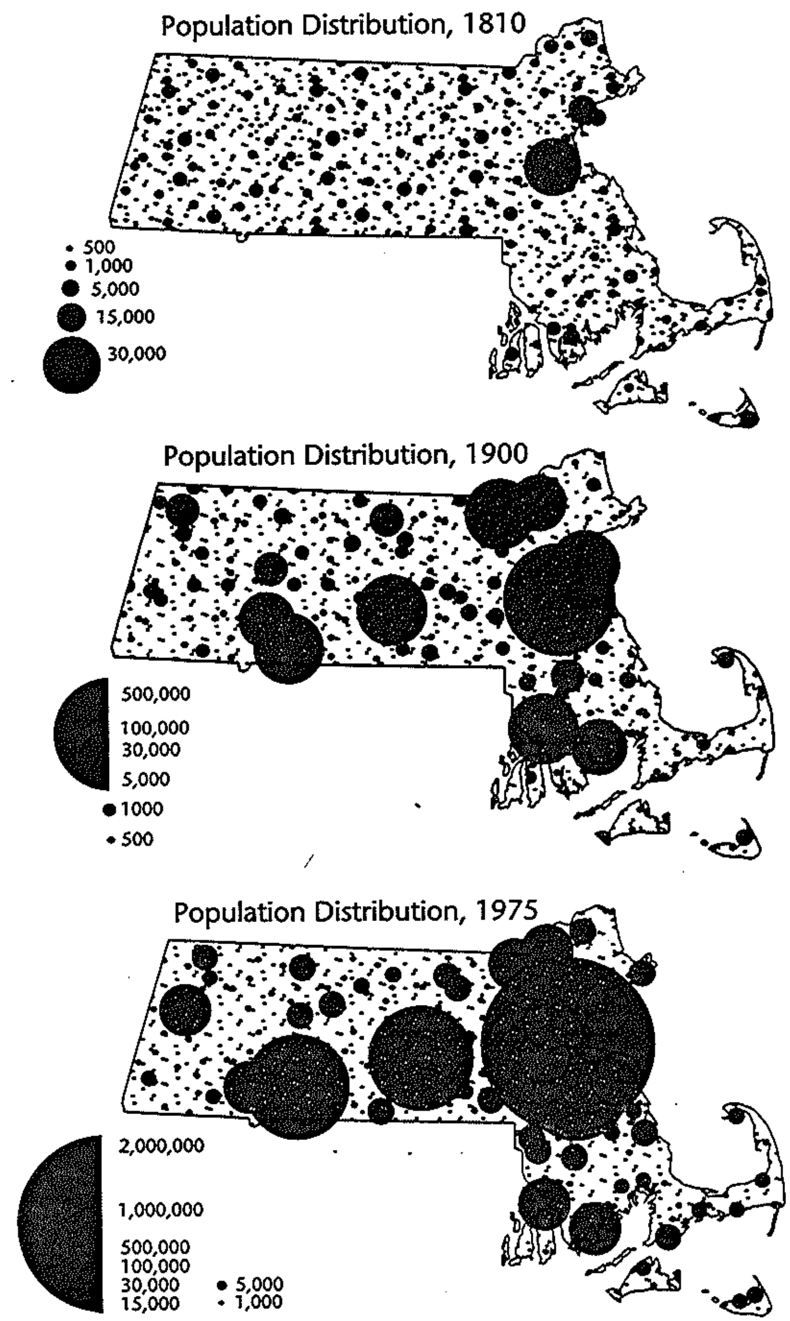
farm products to be shipped from the Midwest more cheaply than they could be produced in Massachusetts.

Many factors contributed to the decline of Massachusetts agriculture, but depletion of the fertility of the land was not a major one. In fact, there is evidence that the quality of tilled land in hill towns improved through the eighteenth and nineteenth centuries (Jones 1991). The disadvantages of Massachusetts farmland included stony soil and small fields divided by numerous stone walls, which were incompatible with mechanization. Industrial production and improved transportation reduced the need for local production and artisanship, and removed opportunities for supplemental income. Social factors contributing to the decline of Massachusetts hill-town agriculture included attraction to the amenities and income of city life, a declining interest in the agricultural life, and shrinking economic opportunities in small towns.

The pattern of decline was strongly influenced by regional geography. Towns adjacent to such developing industrial centers as Worcester and Fitchburg produced fuelwood, market crops, and milk, while those more distant produced butter, cheese, and hay. The farthest-distant towns declined most rapidly (Pabst 1941; Baker and Patterson 1986). Figure 9 depicts the demographic changes as Massachusetts evolved from a dispersed agricultural state in 1810 through urbanization in 1900 toward suburbanization in 1975.

How did our forests fare during the agricultural period? The gradual clearing of the first half of the eighteenth century became a rapid deforestation by the late eighteenth century that continued until the mid-nineteenth century. This clearing was concentrated on the uplands, while the wetter swamps and steep bouldery slopes were generally left as woodlots. The Berkshires were the last areas to be cleared

Figure 9. Population distribution in Massachusetts. In the agricultural period (1810) density was low (412 000 inhabitants) and remarkably evenly distributed (79 percent in rural areas), with the exception of Boston, Salem, and a few other coastal communities. With industrialization and into the twentieth century there has occurred a tremendous increase and concentration of population in urban and suburban centers. In 1975, 85 percent of the population of 5.8 million individuals was located in urban areas. Many of the rural communities have actually undergone a great decline in population during the past 100 years. Data from the U.S. Census with maps modified from Wilkie and Tager (1991).



and never were developed for agriculture to the extent that the remainder of the state was. Figure 7 shows the trends of deforestation and reforestation. The statewide peak deforestation was reached about 1860, by which time nearly 70 percent of the land was cleared. Many areas east of the Berkshires show the pattern exemplified by Petersham and the Prospect Hill tract of Harvard Forest, with maximum clearance in the 1840s, when less than 20 percent of the forest remained. The pattern of remaining forest was strongly influenced by regional as well as local geography (Figure 10). For example, in the north-central portion of Massachusetts from the Connecticut River valley to eastern Worcester County, the hills east of the valley, with many rocky ridges, remained more forested, as did the north-south-trending, poorly drained valleys farther east. Most of the rest of the region was cleared.

Of course, even the uncleared areas were harvested intensively for wood by the nineteenth century. The increasing rural populations, peaking in the mid-1800s, required large amounts of cordwood for fuel. Petersham, for example, had a population of nearly 1,800 people in 1840. Assuming an average household size of six, this population would have represented 300 households to heat. If each household used 15 cords per year (a conservative figure when fireplaces are used), together they would have required 4,500 cords of fuelwood per year. The 20 percent of Petersham that remained forested in 1840 represented about 6,000 acres. Because Massachusetts forests can be expected to grow between one half and one cord of hardwood per acre per year, virtually all the woodland growth in Petersham could have been used for fuelwood. These hardwoods were probably managed by means of a "coppice" system, in which trees would be harvested very young (every 20 to 40 years), left to resprout, and then harvested again as soon as the new growth was big enough to burn. Across upland Massachusetts most farms could maintain woodlots to satisfy their fuel needs, but along the coast, where settlement had been in place longer, and near cities, the fuelwood was soon exhausted and had to be brought great distances by ship at considerable expense.

Although fuelwood represented by far the greatest use of the remaining forests in the early 1800s, the forests also faced other demands. Trees (especially hemlock and chestnut) were cut to provide tanbark for tanneries. Lumber was needed for constructing houses, barns, out-

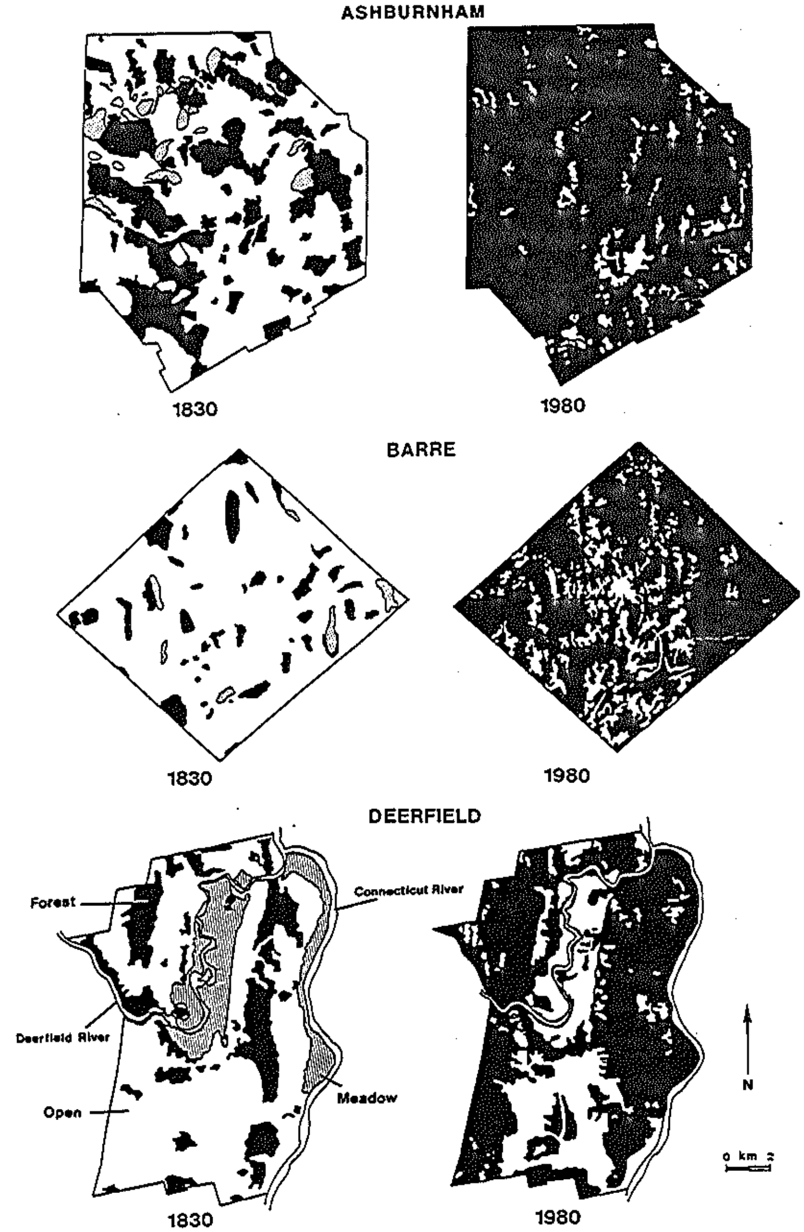


Figure 10. Maps of three townships characteristic of different physiographic regions in central Massachusetts depicting distinctive amounts and patterns of forest, open land, and meadow in 1830 and 1980. Ashburnham, on rocky hills near the New Hampshire border, was least extensively cleared and today is the most forested. Barre, on rolling terrain in the central uplands, was extensively cleared for agriculture but has largely reverted to forest. Deerfield, in the Connecticut valley, was extensively cleared except for a few north-south bedrock ridges and the fertile valley bottom remains in agriculture today.

buildings, and public buildings. Wood was needed for charcoal production, and fences had to be built. The scarcity of wood by the early 1800s probably accounts for many of the stone walls built along boundaries and in pastures, where the stones would not have had to be removed for plowing or mowing. By then stones were much more readily available than wood. Although stone walls took much more effort to build, they lasted much longer than wood fences, as is attested by the miles of stone walls winding through second-growth forests throughout the state today.

Postagricultural and Modern Periods

The decline of agriculture in the second half of the nineteenth century was accompanied by a corresponding regrowth of forest (Figure 8). Our present forest can be divided into secondary forest on land formerly cleared and used for agriculture (plowed or grazed), and primary forest on land never actually cleared but harvested throughout the agricultural period (terminology based on Peterken 1996). As we have seen, the great majority of upland farmland was used for pasture, and even tilled land may have reverted to mowing or pasture before final abandonment. The resulting sod surface was not hospitable to many "pioneer" tree species such as birch and aspen, whose small windblown seeds would often dry out and die after germinating because the sprouting seeds were trapped in the grass unable to reach mineral soil. The sod did, however, provide a suitable seedbed for the windblown but larger seeds of white pine, which colonized vast areas of abandoned farmland. Pines were much less likely to be cut for fuelwood. Several large pines left as shade trees in a pasture or along a fencerow could colonize many acres with dense stands of young pine. Moreover, animals still grazing these pastures would avoid pine seedlings while devouring most broadleaf species.

These new forests grew quickly, and by the late 1800s supported renewed harvesting for lumber and especially shipping containers. The old road system and the new portable steam sawmill, in common use by the turn of the century, permitted logging throughout the backwoods areas. Tremendous amounts of "old-field" white pine were harvested, the volume peaking in 1910–11. During this timber boom, extensive harvesting of all species across the state resulted in the creation of large tracts of even-aged, young, low-value stands. Many of these cut-over

stands, considered nearly worthless at the time, were acquired by the state for overdue taxes and formed the basis of our state forest system. The excesses of the timber industry throughout the East at this time gave rise to the conservation movement, which was strongly represented in Massachusetts.

When the old-field pines were harvested they were unable to sprout from the remaining stumps and roots (except for pitch pine, our only native conifer with this ability) and so had to reestablish themselves on the site from seed. However, as the old-field pines grew, various broadleaf species, including oaks, red maple, cherry, and others, usually were established beneath them as their seeds were either carried in by animals or blown in by the wind. All these hardwoods have the ability to sprout from cut or damaged stems. Therefore, even if they were cut back when the pines were harvested, the hardwoods had a tremendous advantage in succeeding the old-field pines, as they could grow much more quickly from their established root systems than could the tiny pine seedlings. This succession from a first generation of old-field white pine to a second generation of mixed hardwoods has been typical across most of Massachusetts. These changes are beautifully depicted in a series of three-dimensional models, or dioramas, in the Fisher Museum at Harvard Forest in Petersham (Figures 11–15; photographs by John Green).

The proliferation of old-field pine across Massachusetts led to problems as well as economic benefit. The vast expanses of young pines fed an epidemic of a native insect, the white pine weevil. The larvae of this insect eat the terminal buds of young pines, thus killing the leader and releasing the branches in the topmost whorl to replace the leader. The resulting trees have a crook in their growth at best. At worst they divide into multiple, spindly stems. In either case the economic value of the trees is greatly reduced. White pine blister rust, a fungal disease lethal to white pine, also spread rapidly through the tracts of old-field pine. This disease requires an alternate host of the genus *Ribes* (currants and gooseberries) for part of its life cycle. During the 1930s the state and federal governments conducted a massive eradication program for *Ribes* in which men literally marched through the woods tens of feet apart looking for and pulling up wild *Ribes* plants. The prevalence of white pine weevil and blister rust also led to the planting of red pine across the state in the 1920s and 1930s, on many sites where white pine might normally have grown or been

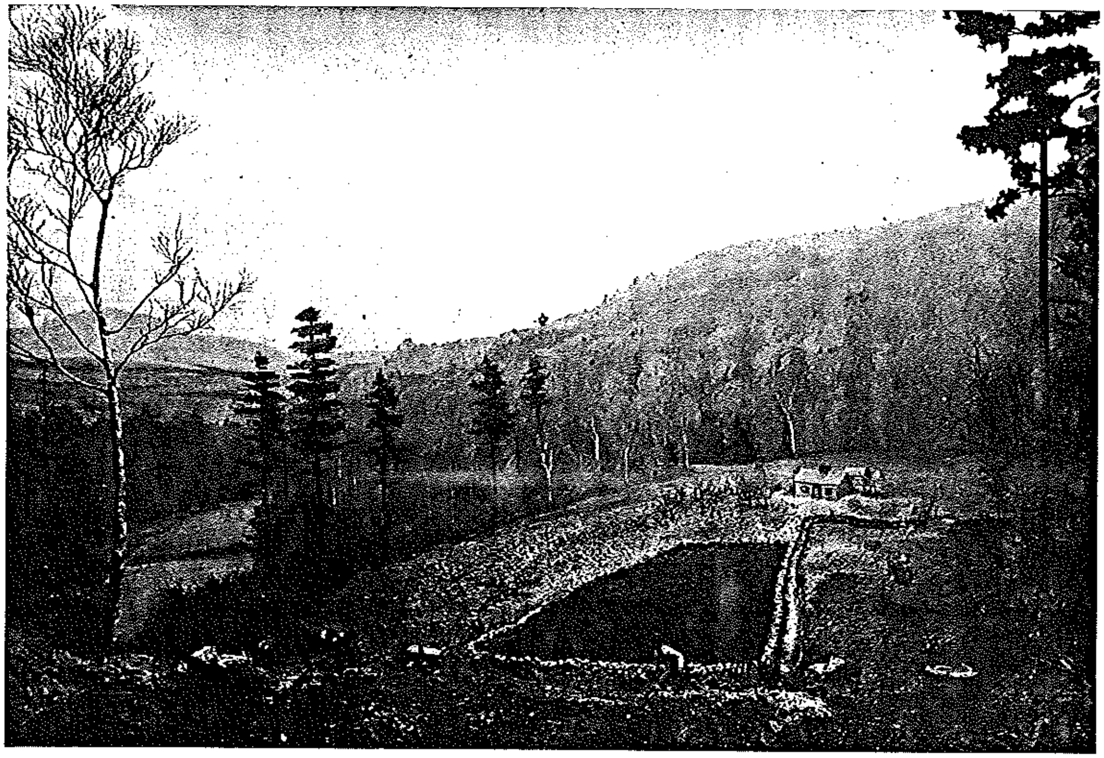


Figure 11. 1740 — Initial clearing and subsistence farming.

Figure 12. 1830 — Height of intensive farming.

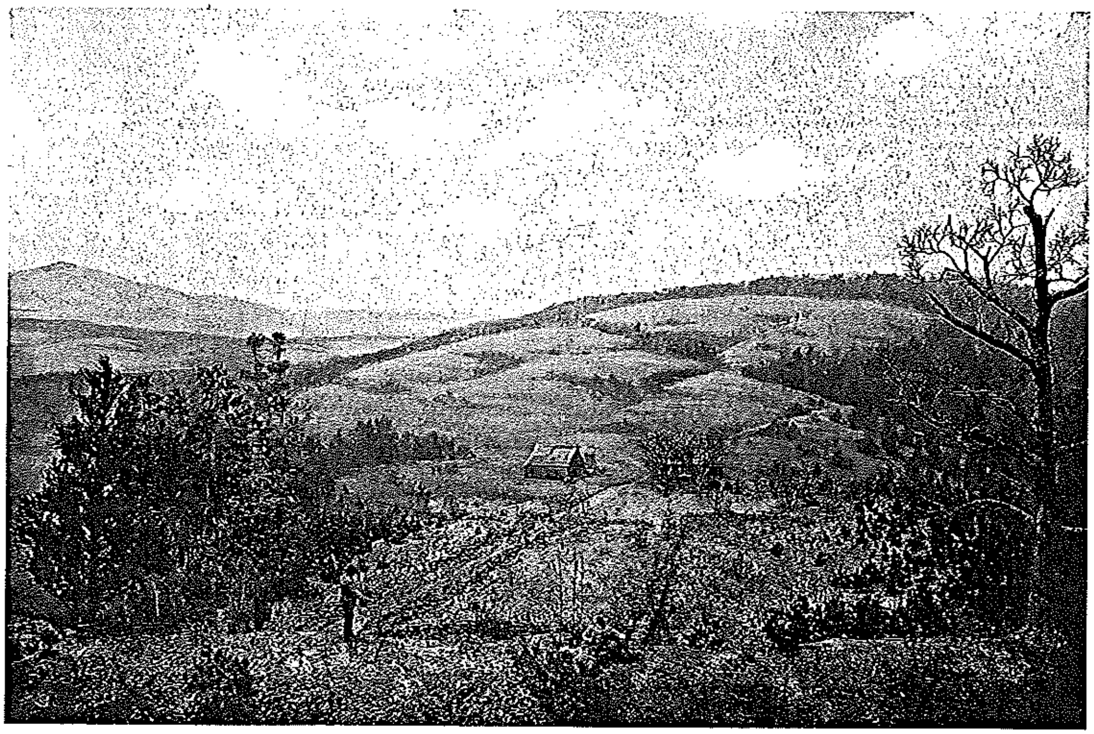


Figure 13. 1850 — Agricultural abandonment and establishment of old-field white pine.

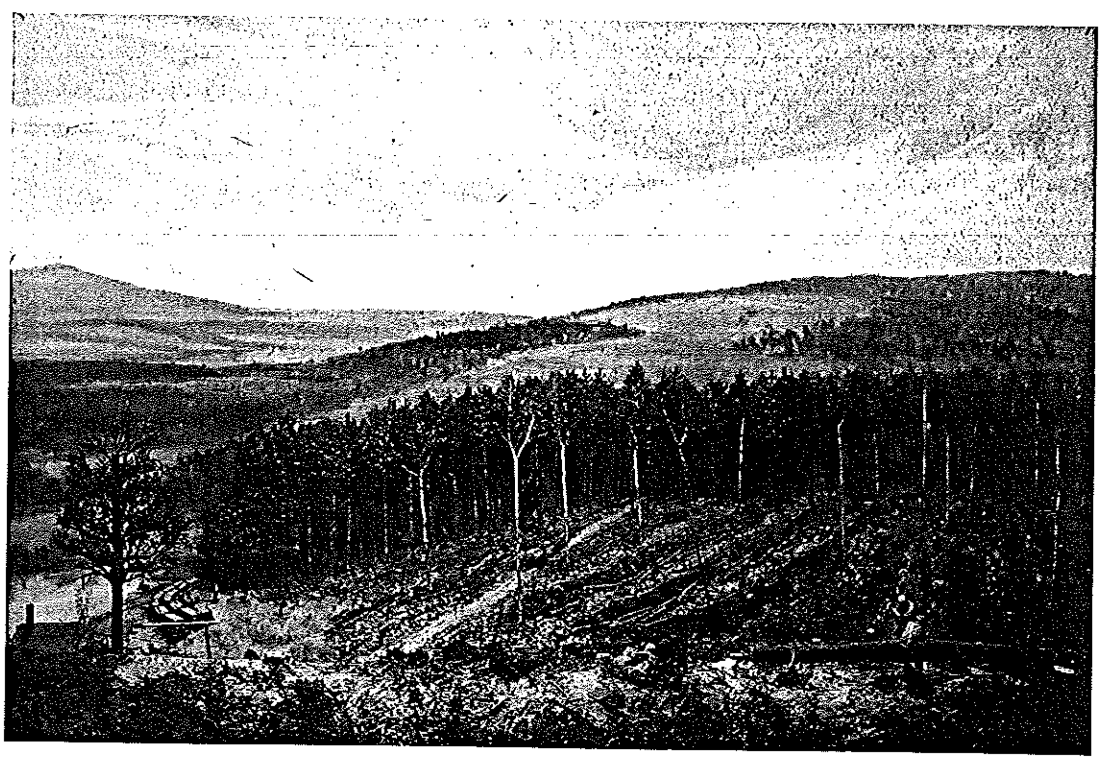


Figure 14. 1910 — First crop of old-field white pine harvested.

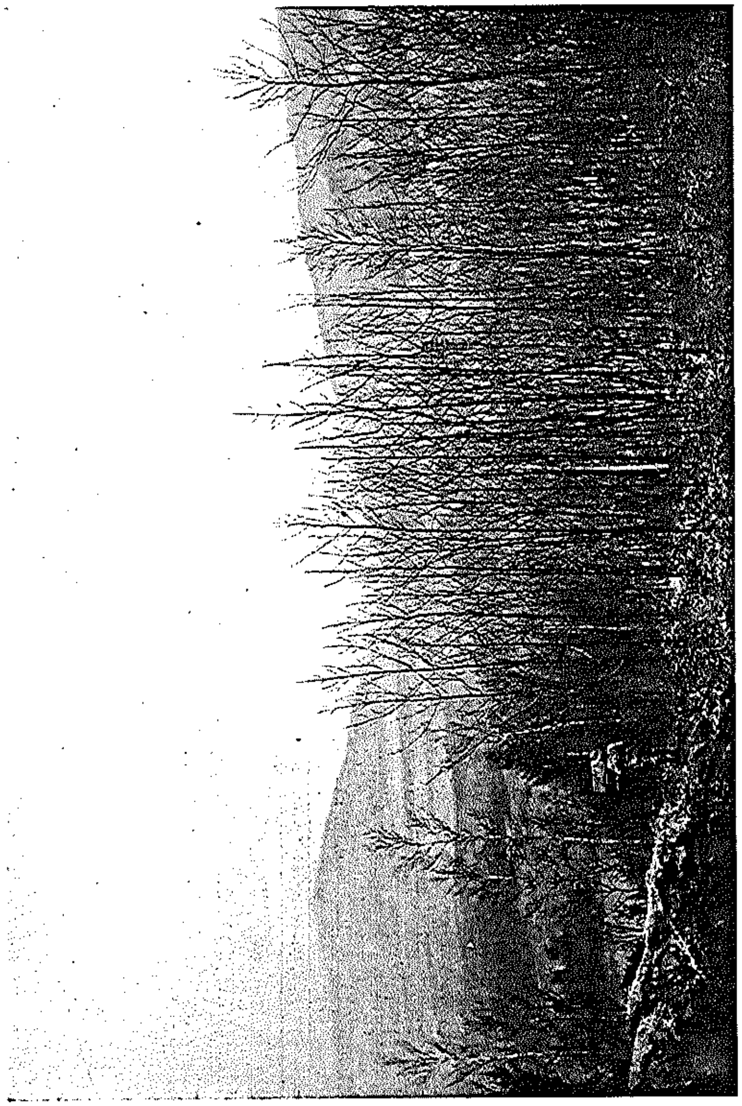


Figure 15. 1930 — The old-field white pine is followed by hardwood.

planted, because red pine is not affected by either pathogen. Although red pine is at the very southeastern edge of its range in western Massachusetts, these plantations have generally done well. Many are now maturing and being harvested.

The extensive old-field white pine stands also played a major role in the most dramatic natural disturbance to affect our forests in the twentieth century, the hurricane of September 21, 1938 (Figure 4). Historically, hurricanes have been a major force in shaping most Massachusetts forests. The 1938 storm followed a track similar to that of other historically significant storms (1788, 1815), but several factors conspired to make it the most destructive storm in our recorded history. The week prior to the hurricane's arrival had been very wet, saturating the soils and predisposing trees to windthrow. The added rain from the storm produced massive property damage from flooding along rivers, compounding wind damage. Large areas of central Massachusetts still supported stands of old-field pine on land abandoned in the late nineteenth century. Even pine stands as young as 30 years of age suffered severe damage if their sites were not protected topographically from the southeast winds. Hardwood stands on similar sites were not as susceptible to damage until they were twice that age (Foster 1988). The expanses of old-field pines set the stage for the unprecedented impact of the storm on our forests, nearly three billion board feet of timber blown down. We had unintentionally created about as vulnerable a landscape as possible. There is evidence that the 1815 storm may have been similar in intensity and path (Figure 4), but it encountered a landscape largely cleared of forest and its impact was quite different.

The vast tracts of blown-down pine presented another problem beyond economic loss and landscape damage, the threat of fire. Fires often follow other disturbances, especially in conifer stands where the resinous foliage and lack of new green sprouts contribute to flammability. With this in mind, and in an attempt to recover some of the value of the blown-down timber, a massive salvage operation was undertaken that recovered much of the windthrown timber. Logging crews were brought in from all over the Northeast, temporary camps were set up, and logs were salvaged and brought to the mills. Because the volume of logs far exceeded the capacity of all the available mills, logs were stored in every available pond in the area. As long as the logs remained underwater, away from oxygen in the air, they were preserved. Many ponds in central Massachusetts were dammed and raised to their present levels in order to accommodate as much salvaged timber as possible. The tremendous volume of lumber produced by the hurricane salvage also drastically lowered lumber values. To stabilize the price, the federal government bought up the vast supply, stamping the end of each log with "U.S." Mobilization for the Second World War finally made use of this vast lumber supply.

Humans have been unwitting accomplices in several other recent forest disturbances as well. With increasing mobility and transport of products, numerous forest pests and pathogens have been introduced from abroad. In many instances these organisms pose special problems because native plants possess little resistance to the exotic pests. Several such "immigrants" have severely affected our forests, and Massachusetts has the dubious distinction of being the introduction site of one major national forest pest. Gypsy moths were introduced into the United States in 1869, when Leopold Trouvelot imported them to Medford with the intention of using them as silkworms to develop a local silk industry. The moths quickly proved unsuited to this use and escaped into the local forests, where they found the native deciduous species, especially oaks and aspen, an ideal food source. Since then gypsy moths have gradually expanded their range, and there have been periodic regional outbreaks during which virtually every green leaf in the forest is consumed, leaving the forest in mid-July looking nearly as barren as in midwinter. Defoliation for two successive years is especially harmful. The outbreak of 1980–81 across the Northeast was particularly severe, causing extensive oak mortality. Today the gypsy moth has spread throughout the Northeast and into the Middle Atlantic and midwestern states and is one of the most destructive forest pests throughout the region.

Probably the most dramatic introduced pathogen to affect our forests has been the chestnut blight fungus. Although the details of the introduction of this fungus are not certain, it was first noticed in New York in 1904, and rapidly spread throughout the range of the American chestnut, passing through Massachusetts in 1913–14. An especially virulent pathogen, chestnut blight is the only disease that has effectively eliminated mature individuals of its host, greatly altering our forests in the process. Chestnut was certainly one of the most useful trees in the nineteenth-century forests, providing abundant crops of edible nuts

annually, bark for tanning, and excellent wood that was beautiful, decay-resistant, and as strong as oak but lighter. It also sprouted vigorously and grew very quickly and therefore increased in areas that were repeatedly harvested (Figure 16). By the early 1920s the large chestnuts had been killed throughout the state, but because the fungus gains access to the trees through cracks in the bark and kills them by preventing transport of water and nutrients past the point of infection, effectively girdling them, the roots and base are not affected and can send out new sprouts. Today these chestnut sprouts are common in our woods. Individual stems are usually killed by the time they become several inches in diameter and the bark naturally develops cracks, only to be replaced by new sprouts. Most of the large chestnuts were salvaged for their valuable wood; their decay resistance, especially within the sapwood, means that many stumps still remain in testimony to the former importance of this species. Chestnut's place in the forest has

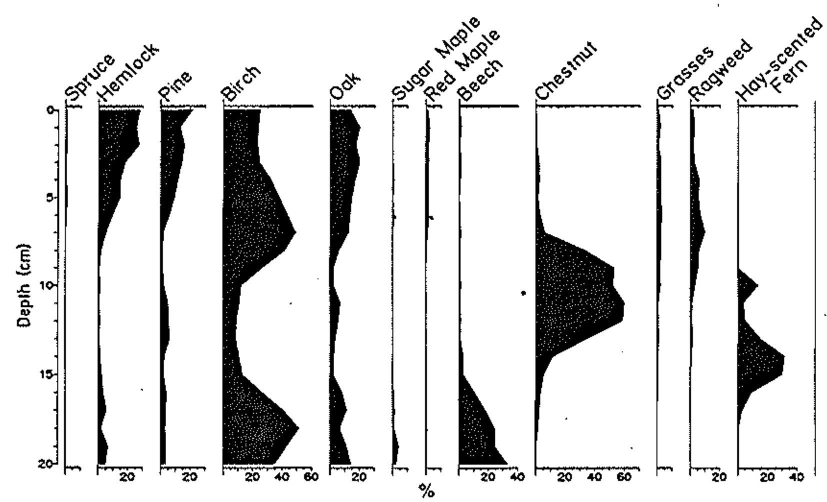


Figure 16. Pollen diagram from the humus soil in a hemlock forest at the Harvard Forest, Petersham, Massachusetts representing the last several hundred years. The site is a primary forest that was never cleared for agriculture but was clear-cut early in the settlement period (at about 18 cm depth in the diagram) and then cut repeatedly for firewood. Tree species respond quite individualistically to the series of human impacts. Chestnut benefited greatly from the cutting activity until it was decimated by blight in 1913. Beech and sugar maple never recovered to presettlement levels of abundance, whereas hemlock, pine, and red maple have gradually increased to the present. From Foster et al. (1992).

been taken by a mixture of species, especially oaks, but its wood and nuts cannot be replaced.

Several other native tree species have also been significantly affected by human-introduced agents, although none so completely as the chestnut. Dutch elm disease, a wilt fungus transported by a bark beetle, dramatically changed the look of almost every town in the state in the 1950s and 1960s as it killed the stately shade trees that lined most of our main streets. The disease is passed from tree to tree by insects aboveground and through root grafts below ground, where the trees are growing adjacent to each other, as in street plantings. This disease was somewhat less traumatic in our forests because elm occurred in mixed stands, primarily near wetlands, and exhibited a greater range of natural resistance than did chestnut. The devastation of the elms in our urban tree stands again demonstrates the susceptibility of human-induced monocultures to various pathogens. More recently, many of our beech trees have been disfigured and killed by beech-bark disease. This disease, caused by the coincident impact of a fungus and a scale insect working together, is spreading steadily south after being introduced into the Canadian Maritimes. Most recently, hemlock woolly adelgid is beginning to cause mortality in the southern Connecticut River valley area and has been reported from many other areas of the state as it slowly advances north. This aphidlike insect, introduced on nursery stock from Japan to the West Coast and then to Maryland, poses an extreme threat to hemlock forests because hemlocks have shown little resistance and are incapable of sprouting. Moreover, because of the steep habitats many hemlock stands occupy and the unique microenvironments they create, loss of hemlock would cause extreme changes in many of our forests.

Logging and land conversion to suburban use are the two direct human changes that have most affected our forests over the past several decades. Regrowth after the old-field pine stands and other forests were cut early in this century, and after the 1938 hurricane, has provided an abundant middle-aged and maturing forest, much of which has been and is being harvested with varying intensities. Environmental disputes resulting in limitations on harvesting on federal lands in other regions of the country and a strong export market have put added harvesting pressure on Massachusetts forests. However, despite these pressures the average size of trees in our forests has been steadily increasing (Figure

17). In some instances we have even managed to reduce the impact of suburban development on the forest. Significant numbers of people are now building homes on large forested lots, clearing only immediately around the buildings, and some developments cluster buildings together, reserving the majority of land as forest or open space. While both of these patterns of development alter the forest, they are much less destructive of it than traditional tract development.

Wildlife species have very much been influenced by human-induced changes in the landscape as well as by hunting (Figure 18). Although much of this information is indirect and difficult to gather, most of the large, broad-ranging species were probably largely eliminated during the initial period of forest clearance. This group would include elk, wolf, mountain lion, and moose. Deer were nearly eliminated by the mid-1800s. However, being an edge species, utilizing both open areas for browsing and forests for cover and tolerating human activities, deer have responded so favorably to the return of the forest that they have reached densities detrimental to the vegetation in areas where they are not controlled by hunting (Kyker-Snowman 1989).

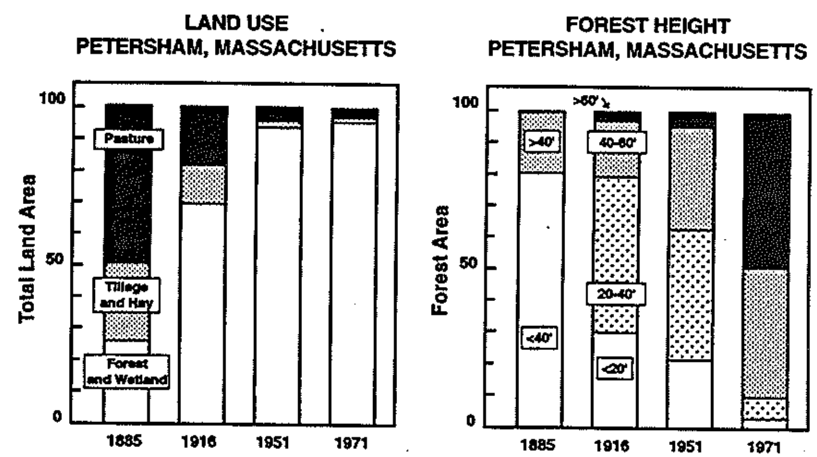


Figure 17. Historical trends in land-use activity and forest structure for the town of Petersham, Massachusetts, during the period of farm abandonment and reforestation. Note that the 1885 data for height structure depicts 40-foot height classes, whereas the later years depict 20-foot height classes. As the township became increasingly covered with forest, there occurred a progressive aging and height increase in the extant forest. Sources include Cook (1917), Rane (1908), and MacConnell and Niedzwiedz (1974).

Beavers were extirpated by the 1700s owing to the value of their pelts. They were successfully reintroduced in 1928 in West Stockbridge and have subsequently expanded to overutilize existing habitat. More recently, wild turkeys have been reintroduced very successfully, and moose have returned on their own as their northern populations have continually increased and migrated south. These three species are all responding to the expansion of our woodland area, as have black bear and fisher which have significantly expanded their ranges and numbers within the past 75 years. Other species, most notably open-land birds such as the bobwhite and meadowlark, have decreased as the forest has regrown and matured.

V. PRESENT CONDITIONS AND FUTURE PROSPECTS

How are the forests produced by the series of human changes since European settlement, in some cases interacting with natural disturbance processes, different from the forests the colonists found? The process of deforestation and reforestation produced different landscape patterns in different places, depending on the distribution of natural

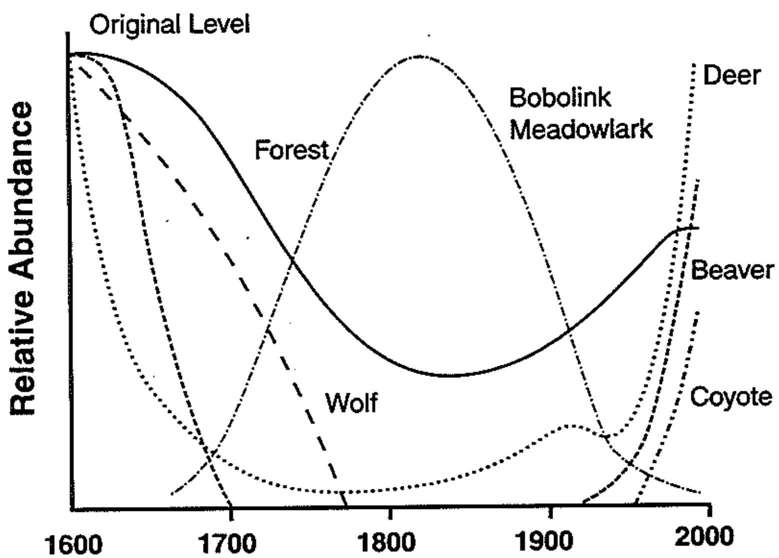


Figure 18. Changes in the relative abundance of selected animal species in Massachusetts over the past 400 years. Whereas the wolf has been eliminated, beaver have been reintroduced and the coyote represents a new species in the landscape. Modified from Bickford and Dymon (1990).

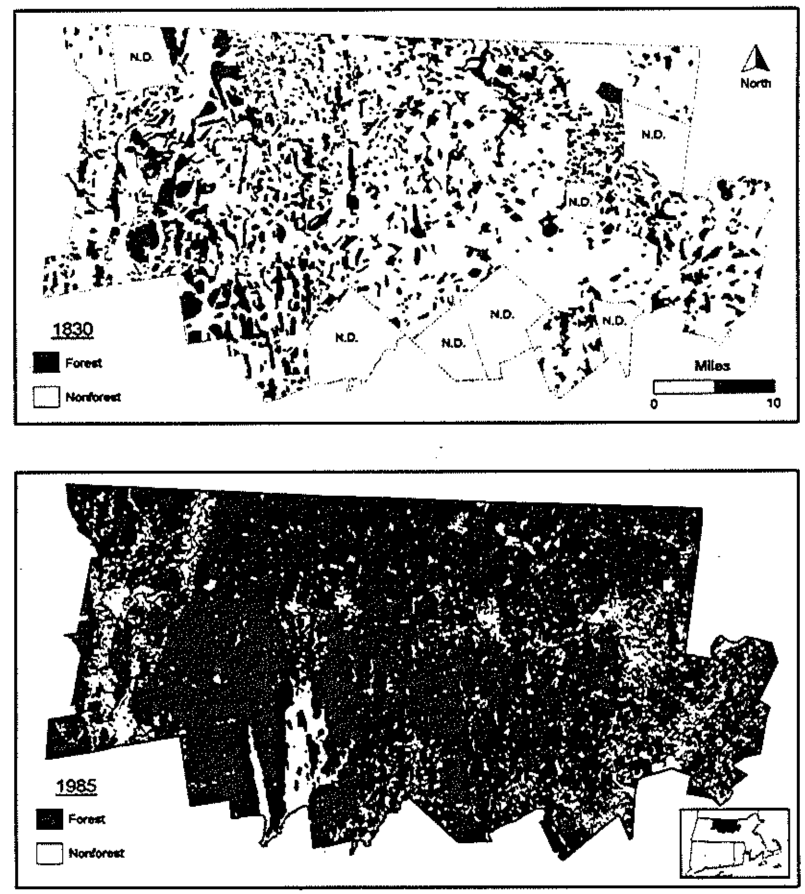


Figure 19. Forest cover (black) for north-central Massachusetts in 1830 at the approximate peak of agricultural clearance, and in 1985. Major physiographic regions from west to east include the Connecticut Valley, the rough Pelham Hills, and the undulating central upland regions. ND = no data. From Foster et al. (1998).

and subsequent cultural features, including river valleys, wetlands, steep slopes, rock ledges, town centers, and highways (Figures 8, 10, 19).

Today, open, agricultural land is primarily restricted to broad river valleys and the crests of broad ridges. Urban areas first developed along the coast and along major rivers, then along the railroads, which tended to follow the rivers. More recently, suburban development has occurred along and especially near the junctions of major highways. Today, forests predominate outside these zones, and in protected reserves and some wetlands within them, and are under the greatest pressure at the edges of these zones (Figure 20).

The major changes in the geographic pattern and stand structure of our forests have strongly favored a new landscape of even-aged forests and sharp boundaries between forest types. Agricultural clearing and abandonment, heavy fuelwood cutting, intensive harvesting of old-field pine and other species early in this century, and the 1938 hurricane with its subsequent salvage harvesting have all pushed our forests toward an even-aged condition. Land-use regulations and land ownership boundaries create visible differences that tend strongly to be perpetuated through time and subsequent ownership changes. General trends in field size, farm size, and regional timber harvesting practices have worked to impose a repetitive patchwork of forest classes on top of the natural vegetation patterns described early in this chapter. The even-aged structure and imposed pattern present across much of our forest today increase the potential for future disturbances to be more damaging than they might be in a more diverse forest. Moreover, the relative lack of very young forests presents problems for species dependent on such habitat.

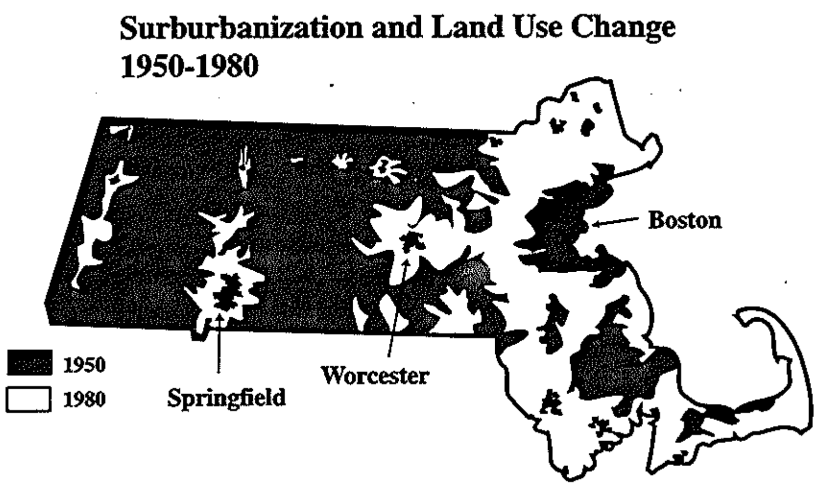


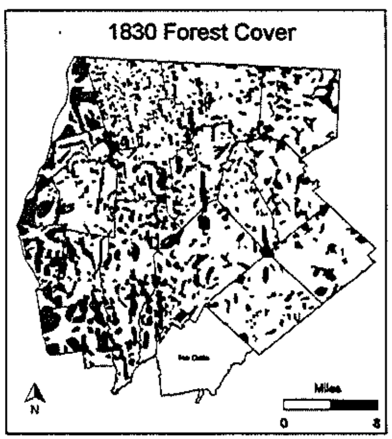
Figure 20. The progression of suburbanization in the state of Massachusetts during the last half of the twentieth century. A growing population and an improved road transportation system have resulted in a conversion of former agricultural and industrial towns to residential communities around the major cities of Boston, Worcester, and Springfield. Modified from Wilkie and Tager (1991).

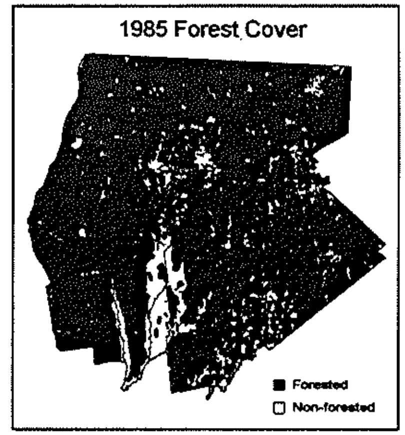
Ever since the heavy fuelwood cutting in the early 1800s, there have been repeated public concerns about the condition of our forests. As Figure 17 shows, over the past 100-plus years the forests in Petersham have continually increased in area and size, and this trend has been general throughout the state. How has the composition of our forests been affected? Agricultural clearing and subsequent abandonment led to the dramatic increase in white pine discussed previously. Prior to European settlement white pine was probably found principally on sandy outwash soils, on sites heavily burned by Indians or following a natural disturbance, and as scattered, emergent individuals in old stands. Following agricultural abandonment, especially of pastures, white pine proliferated throughout most of the state on sites it would never have occupied in the absence of clearing and grazing. Despite intensive harvesting and the 1938 hurricane, white pine remains much more widely distributed and dominant today than it was before. The repeated fuelwood cutting and agricultural burning practiced in the nineteenth century would have favored an increase in invasive, pioneer species intolerant of shade such as gray and paper birch, aspen, pin cherry, and black cherry, as well as species that sprout prolifically such as chestnut, oak, red maple, birch, and hickory. Chestnut is probably the species that responded most favorably to nineteenth-century disturbances because it sprouts prolifically from dormant basal buds and is capable of phenomenal rates of height and diameter growth when reproducing vegetatively (Zon 1904; Paillet and Rutter 1989).

Figure 16 traces the changes in tree species abundance from the agricultural period to the present, as recorded in the pollen collected in the humus soil in a hemlock woodlot in Petersham. The most striking feature is the tremendous increase in chestnut followed by its virtual elimination following the blight. The other major changes are the decreases in several long-lived, shade-tolerant species, including hemlock, sugar maple, and beech, during the agricultural period. Both hemlock and beech are very sensitive to fire and could be largely eliminated from upland areas by repeated fires, a rather common agricultural practice. The site represented in Figure 16 is a moist lowland, and hemlock has become dominant there following the loss of chestnut to the blight. Oak, pine, and red maple have also increased, replacing beech and sugar maple.

As our forests have grown back and matured following the tremendous cutting at the turn of the century, the loss of chestnut in the teens, and the 1938 hurricane salvage, in conjunction with our more recent suppression of fires, there has been an increase in long-lived, shade-tolerant species, including hemlock, sugar maple, and to a lesser extent beech. However, these species, especially beech, remain well below their presettlement distributions based on early survey and pollen records. Oak, which requires at least moderate disturbance for successful regeneration, may be generally more common than before settlement.

The recent maturation of considerable areas of Massachusetts forest has led to significant new harvesting. At the same time, the developing environmental consciousness from the 1960s to the present has increased awareness of what is happening on our woodland and has led to the regulation of forest cutting practices (Massachusetts General Laws, chapter 132, sections 40–46), which, in turn, has increased the quality and extent of professional forest management across the state. Moreover, the requirement to file a cutting plan that includes a map for all harvests greater than 25,000 board feet has enabled the compilation of maps of current harvesting patterns (Figure 21) at much finer detail than has been possible in the past. The growing understanding that forest stands or ownerships do not function in isolation but must be considered within a regional or ecosystem context (for example, with respect to disease spread or wildlife habitat) points up the importance of such regionally mapped information.





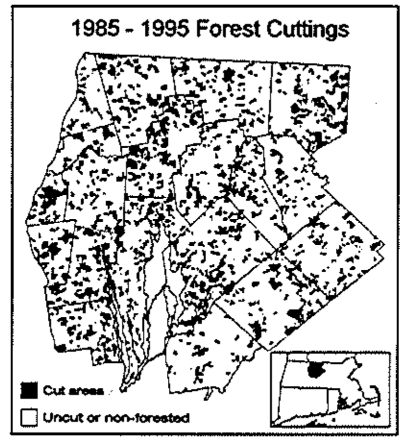


Figure 21. Maps of the north Quabbin region of Massachusetts showing forest cover at the height of agricultural clearing (1830) and in 1985 and the areas on which some type of forest cutting was conducted during the period from 1985 to 1995.

The growing environmental interest has led to the discovery of remnant patches of old-growth forest, once assumed to have been entirely eliminated through the extensive clearing and harvesting in the nineteenth and early twentieth centuries (Figure 22). Although exact definitions of these remnants of the presettlement forests vary considerably, these areas typically contain dominant trees well over 200 years old and show minimal evidence of human disturbance. At present between 500 and 1,000 acres (depending on exact definition and extent of disturbance allowed) of old-growth forest are recognized in Massa-

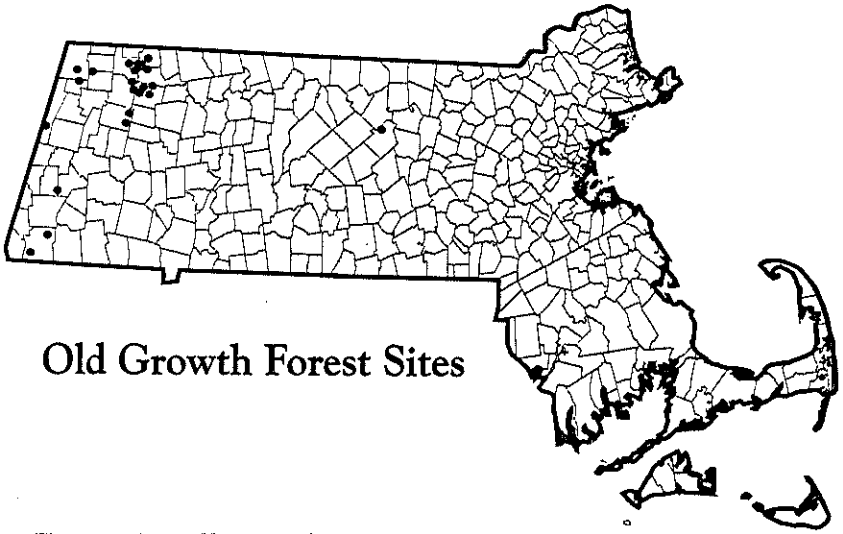


Figure 22. General location of currently recognized old-growth sites (at least 10 acres) in Massachusetts. The majority of these sites are on steep, rocky slopes along the headwaters of streams in western Massachusetts that were unsuitable for agriculture and inaccessible to harvesting. Adapted from Dunwiddie and Leverett (1996).

chusetts (Dunwiddie and Leverett 1996), and this amount continues to increase as more areas are investigated by scientists with increasingly better understanding of what they are looking for — which is not necessarily huge old trees. Many of these remnants are small patches of barely 10 acres — which according to one current, working definition is the minimum size necessary to prevent significant edge impacts — but some are considerably larger. Most are located on steep, rocky slopes, often on headwater streams, where they were inaccessible for harvesting from either the stream valley or the broad ridges and were somewhat protected from natural disturbances.

Not even these sites offer protection from some recent human disturbances, which are subtle but pervasive. These include atmospheric pollution and rising carbon dioxide (CO_2) levels, with implications for future global warming. While neither of these forces has had serious, measurable impacts on our forests as yet, both have the potential to significantly alter them in the future.

Inputs of atmospheric nitrogen (NO_x), an important component of atmospheric pollution, increase as one moves farther west and to greater elevations in Massachusetts (McNulty et al. 1990). Nitrogen is

the major limiting nutrient for plant growth in our soils. Initially nitrogen works as a fertilizer, but at higher concentrations it may saturate the soils and become damaging, even leading to nutrient loss through leaching (Aber et al. 1989). Low-level ozone is another pollutant with potential serious forest impacts. Pollutant impacts are extremely complex, and the effects of long-term chronic exposure to and accumulation of these compounds is still largely unknown.

Elevated carbon (CO_2) levels affect plant growth, competitive interactions, leaf chemistry and thus organic-matter quality, as well as potentially changing the global climate. We do not yet understand how forest communities and ecosystem processes might ultimately be changed by elevated CO_2 levels, nor do we know the local effects of global warming. Massachusetts forests do have some impact on the global CO_2 level. Because they are still relatively young and growing, and our landscape is still recovering from agricultural clearing, our forests take up and store significant amounts of CO_2, slightly offsetting the increases from fossil fuel burning and deforestation. CO_2 levels and pollution are both international issues that will require unprecedented levels of cooperation if they are to be managed.

CONCLUSIONS

We have traced changes in Massachusetts forests from a time when there were no forests through natural forest development and change, aboriginal impacts, European settlement and forest clearance, reforestation and regrowth, and down to the present, when the state is nearly two-thirds forested again. What comparisons can be made between change under natural processes and the more recent changes from human disturbances? Although our forests have been very dynamic throughout geologic and historical time, human-induced changes over the past 300 years have been much more frequent, varied and extensive than most changes in previous forest evolution (Table 2). These changes were superimposed upon natural disturbance processes, and where they interacted, as in the 1938 hurricane, the impacts were substantial. On the whole, human disturbances have been more frequent and more systematic in both time and space than their natural counterparts. Human activities have tended to mask natural forest patterns by overlaying imposed patterns on them and homogenizing them.

Table 2. Forest disturbances through time with their impacts scaled as low, moderate, or high on four measures: frequency, area, community (species) changes, and geographical specificity. There is a general trend toward increasing frequency, area, and community change and decreasing geographical specificity in the post-European settlement disturbance period.

	Frequency			Area			Community			Geographical Specificity		
Disturbance	L	M	H	L	M	H	L	M	H	L	M	H
Migration	■	■				■	■	■		■		
Pathogens	■					■	■	■		■		
Fire (natural)	■	■		■			■					■
Windstorm–Hurricane	■	■			■		■	■			■	■
Windstorm–Downburst		■		■			■	■			■	
Fire (aboriginal)		■	■	■	■		■				■	■
Agriculture			■			■			■		■	
Logging			■		■	■		■	■	■	■	
Introduced pathogens			■			■		■	■	■		
Pollution			■			■		?		■		

L = low; M = medium; H = high

The forests across the state today are quite different from those the colonists and Indians saw — quite different from those 60 years ago. Undoubtedly they will continue to change, but will likely continue the recent trends of increasing in volume and storing carbon. Changing ownership patterns will increasingly affect forest development. Over the past 50 years the average size and term of forest ownership have both consistently shrunk, as more people have found their place in the woods and as our population has become even less agrarian and much more mobile. These trends, along with expanding low-density development on wooded lots as suburbs encroach on rural areas, will certainly influence our forests and their management into the next century. At the same time, demands for forest conservation, preservation, and recreation will all probably increase, especially on public lands, as the amenity, recreation, and watershed-protection values of our forests increase even more rapidly than their resource or development values. Humans — directly, indirectly, and in conjunction with natural processes — will continue to be the dominant force acting on our forests, which are certain to change. The forests covering nearly two-thirds of Massachusetts today are testimony to the resilience of our landscape in the face of centuries of unplanned human activity and natural disturbance. However, as we continue to increase the stresses on our forests, we will need to use our increasing understanding of forest ecology and history to plan for a future in which the forests will continue to meet our demands for both amenities and products.

As long as they have lived in Massachusetts people have influenced the forest, and the forests have influenced the people. Hugh Raup, former director of the Harvard Forest, once suggested that "the principal role of the land and the forests has been that of stage and scenery: the significant figures have always been the people, and the ideas they have had about what they might do at specific points in time with the stage properties at hand. At each such point in time an actor could play his role only by the rules he knew — in terms of his own conception of his relation to the play of which he was part" (Raup 1966). A closer examination of some of these roles occurs in the chapters that follow.

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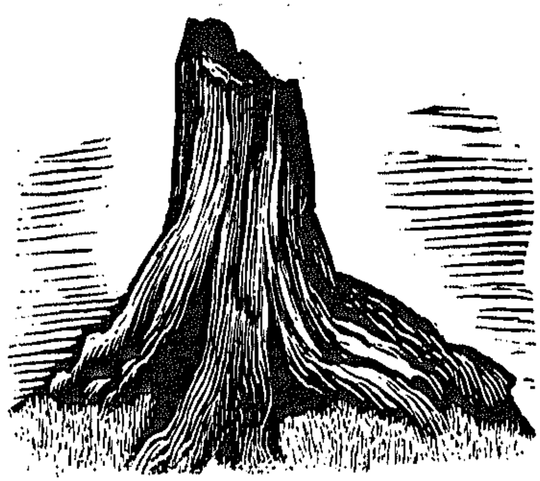

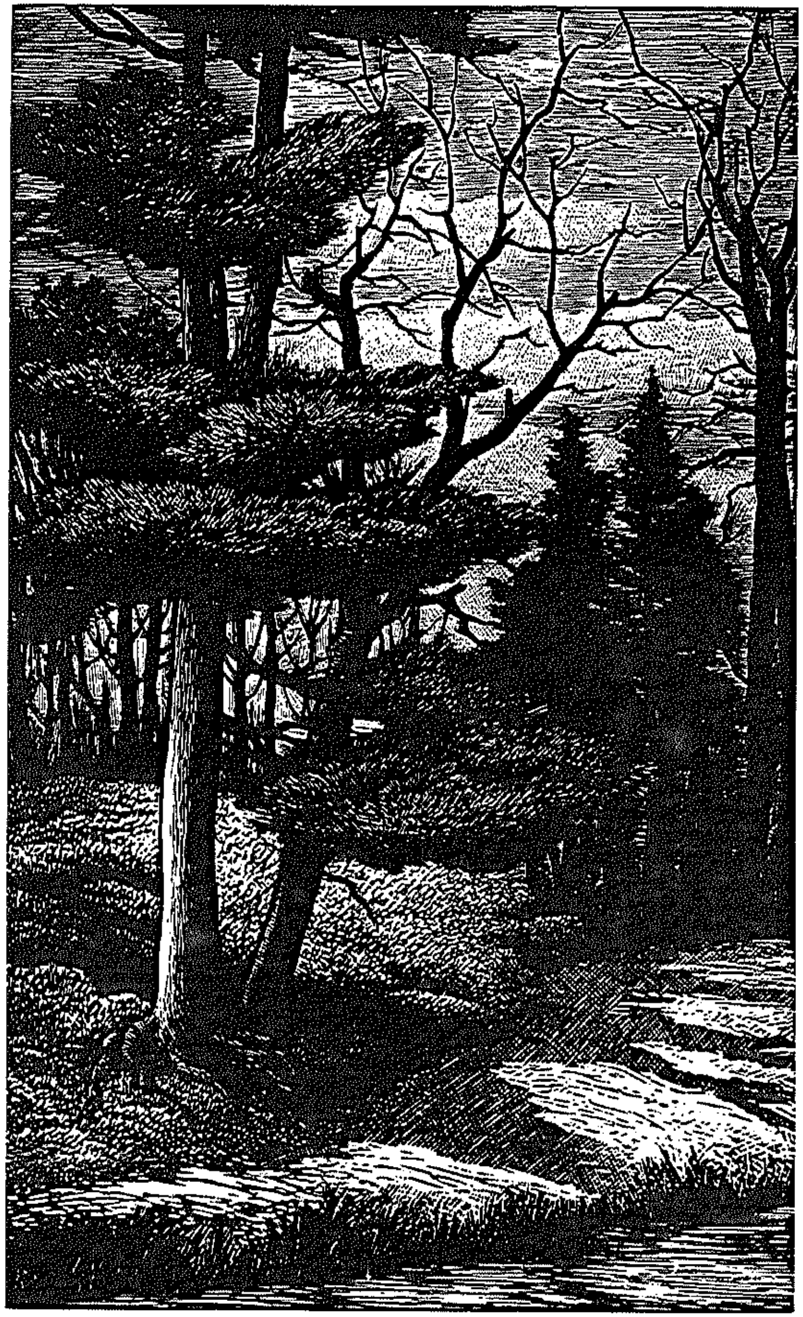

Stepping Back to Look Forward

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