9

Land-use History and Forest Transformations in Central New England

David R. Foster

Most of the northeastern U.S. has been extensively altered by human activity over the past 200-300 years. In New England, much of the landscape was deforested, farmed in diverse ways, and eventually allowed to reforest naturally. Any understanding of the forest vegetation and ecosystems of this broad region, therefore, requires close consideration of human impacts, past and present, and their continuing effects over the modern landscape (Cronon 1983). At the Harvard Forest, the effect of human history on structure and management of forests in central New England has been a focus of study for foresters (Fisher 1925, 1931; Spurr 1956), soil scientists (Gast 1937; Griffith et al. 1930), economists (Gould 1942; Black and Brinser 1952; Barraclough 1949), and ecologists (Fisher 1928, 1933; Raup and Carlson 1941). Today the Long-term Ecological Research program continues to compare and contrast the effects of human and natural disturbance processes (Foster and Smith 1991).

One major theme that emerges from these diverse studies is that at a range of scales, from the stand to the region, the forest vegetation of central New England has been in a constant state of flux in response to dynamic and ever-changing modes of human activity. Changes in the structure, composition, and pattern of forest during the last three centuries have produced a sequence of unique landscape mosaics that are distinctly different from the landscape during the pre-settlement period. The human impacts to the forest ecosystem have not only altered the type and arrangement of forests, but the manner in which the forests function and respond to natural processes. In turn, these changing conditions and responses may affect the research emphases that scientists have pursued in this region and the conclusions that have been drawn.

In the following discussion I examine forest change across different

Humans as Components of Ecosystems
edited by Mark J. McDonnell and Steward T. A. Pickett

spatial scales resulting largely from the impact of European settlers. First, the history and underlying causes of human impacts are outlined. On a township to regional scale, changes in forest extent and pattern, as well as composition and structure, are examined from the pre-settlement period. The complexity and dynamics of these forest transformations are then investigated through the detailed history of pre-settlement and post-settlement disturbance processes and the dynamics of a single woodlot that was extant throughout the period of intensive agriculture.

Regional Characteristics of the New England Landscape

Physical and Biological Features

The New England states, excluding Maine, form a roughly rectangular area 250 by 450 km in size that extends north and west from the Atlantic Ocean. Physiographically, the region consists of six broad areas, the coastal lowland, central uplands, the Connecticut River Valley, and the White Mountains, Green Mountains, and Taconic Mountains. The geological substrate is comprised predominantly of acidic, nutrient-poor material with surficial deposits left by the last glaciation 10,000-13,000 years ago. In general, the soils are shallow and bedrock is extensively exposed.

Substantial variability in regional climate results from elevational and coastal-inland gradients. Average annual rainfall exceeds 100 cm and is evenly distributed through the year. Summer temperatures (July) average 22°C whereas winter averages drop to -4°C (January) in inland locations. Regional differences in growing season length exceed three weeks between the south coastal and northern locations.

The regional vegetation changes latitudinally, with local variation due to elevation in the Connecticut Valley and northern mountains (Fig. 9.1). Northern hardwoods-conifer forest extends southward into northern Massachusetts. Important hardwood species in this forest include sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), paper birch (*Betula papyrifera*), and red maple (*Acer rubrum*). Among the conifers, red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*) are common in the north, whereas hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*) increase to the south. Southern New England forests (Central Hardwoods) include more oak (*Quercus alba, Q. velutina, Q. rubra*), gray birch (*B. populifolia*), and hickory (*Carya ovata, C. cordiformis*), along with red maple and hemlock. A transition forest including elements of both the southern and northern community occurs across central Massachusetts, up the Connecticut River Valley, and through eastern New Hampshire. A distinctive vegetation of pitch pine (*Pinus rigida*) and

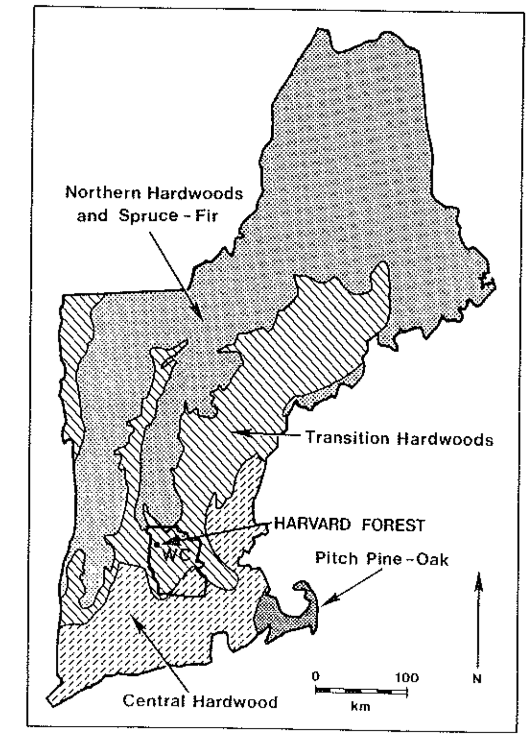

Figure 9.1 Forest vegetation of New England showing the Harvard Forest in Petersham, Massachusetts, and the outline of Worcester County, Massachusetts, USA.

oak (*Q. ilicifolia, Q. stellata*) species occurs on sandy soils across Cape Cod and inland on outwash deposits.

Post-settlement History of Central New England

The forest changes during the past 300 years are a response to a human history that was dynamic in population size, technology, mobility, economic structure, and intensity of interaction with the landscape. These factors, in turn, were largely driven by broader social, economic, and scientific developments operating externally to the township and region. The history of human activity and, therefore, of forest change appears to be much more a consequence of this external social environment than a result of changes in the physical environment (e.g., climate) or edaphic conditions (e.g., soil fertility) (Raup and Carlson 1941; Black and Westcott 1959). As summarized by Hugh Raup (1966), "The land itself did not change. Only the people's ideas changed in response to...ideas brought to bear from outside the region."

In the upland hill towns of central Massachusetts, history of land-use activity has gone through the four major phases described below for the town of Petersham. Regional differences occur with respect to proximity to urban areas and markets or access to transportation. However, similarities in human and landscape histories across central New England corroborate the existence of general trends.

1730 to 1790: Settlement and Low Intensity Agriculture

Following the layout of the township of Petersham in 1733, the first settlers dispersed across the landscape, establishing homes and the earliest farms. Individual farmers cleared 1-3 acres annually through cutting, girdling, and burning of trees; wood had little value other than for fuel and local construction. The mixed agricultural activity of most families included raising crops and livestock for home consumption and barter, with an increasing emphasis on wood and beef production through time (Jones 1991; Garrison 1987). Although this early settlement lifestyle of low-intensity farming is commonly termed "subsistent" (Bidwell 1916; Gould 1942; Black and Westcott 1959), it is abundantly clear that there was great interdependence within the local population and that trade and exchange occurred throughout the region at an early date (Stow 1853; Pruitt 1981; Baker and Patterson 1986). Few individuals maintained the livestock, equipment, skills, or acreage to provide all of their household and nutritional needs, rather, there was a continual trade of labor, services, and goods (Gates 1978; Garrison 1987). Roads were poor and yet cattle and sheep could be driven to regional markets. Trips to Boston, Hartford, Springfield, and Worcester are noted regularly in accounts of the day (Bogart 1948; Gates 1978; Rothenberg 1981; Baker and Patterson 1986).

1795 to 1860: Commercial Agriculture and Diversified Industry

The late eighteenth century brought a major transformation in the economic setting of central New England and in the focus of human activity (Bidwell 1916; Baker and Patterson 1986; Merchant 1989). With regional population growth, the development of villages and small urban areas, and improved transportation, the hill towns of central New England developed a market focus for agricultural products and small industrial goods (Davis 1933; Raup 1966; Jones 1991). Improvements in the turnpike and railroad system across Massachusetts allowed access to distant markets and created new local ones in the developing mill towns (Kimenker 1983). Farmers in towns like Petersham responded to these market opportunities by greatly increasing their production and by concentrating on a restricted number of products (Baker and Patterson 1986). Specialization in perishable goods (beef, cheese, and butter) and bulky items (hay, firewood, potash) involved the increasing use of marketmen and drovers and the development of a cash economy (Pabst 1941; Munyon 1978; Baker and Patterson 1986). Forest land was cleared extensively for agricultural development and forest products; at the peak of forest clearance around 1860, many of the hill towns in central New England supported forest on less than 25% of the uplands. Home industry produced such wares as straw hats and shoes (Gould 1942), whereas local workshops manufactured wooden wares and leather goods, and processed farm products (Brown 1895). The population peaked in many hill towns near the middle of the nineteenth century during a period of relative prosperity and stability (Doherty 1977).

1865 to 1935: Agricultural Decline and Commercial Logging

The development of regional urban centers and the expansion of valley towns, based on industrial development presented an attractive alternative to the rural life for many villagers. This, plus agricultural competition from the midwest and general changes in social structure brought on by the Civil War and industrialization, prompted many families to sell their hill farms in the late 1800s (Chase 1890; Peters 1890; Brown 1895). Lands were consolidated by neighboring farmers (Torbert 1935; Gates 1978) or were purchased by outsiders on speculation or as country estates (Lutz 1938; Mann 1889; Currier 1891). Marginal farmland was neglected and allowed to reforest naturally. In the 50-year period before 1900, more than 9 million acres of farmland was reforested in New England with more than one million of these located in Massachusetts (Barraclough and Gould 1955). By 1920, over 30% of Massachusetts villages had lower populations than in 1870 (Black and Brinser 1952). Agricultural activity became geographically concentrated around the manufacturing and urban centers and focused on dairy products, wood, and hay (Davis 1933; Pabst 1941; Black and Brinser 1952).

In Petersham and much of central New England, reforestation of abandoned agricultural fields with even-aged stands of white pine or hardwoods including chestnut stimulated the development of a thriving, though relatively short-lived, timber industry (Raup 1966; Barraclough and Gould 1955). Producing lumber, container materials (boxes, crates, barrels), and furniture, this industry prompted broad-scale cutting in the late 1880s (Gould 1942), peaked in 1910 (Raup 1966; Cook 1961; Black and Westcott 1952), and declined through 1930. Much of the economic return from this activity went to out-of-town landowners and lumber mill operators (Lutz 1938).

1935 to 1990: Modern Period

Through the 1920s and beyond, the once-thriving woodworking industries of central New England declined as new forms of packaging replaced wood containers and as the quantity and quality of old field white pine (*Pinus strobus*) decreased (Fisher 1925). Farming activity lessened with declining milk prices and the rising labor costs and tax burden on farmers (Gould 1942). Regionally, there occurred an increasing shift to part-time farming, continued abandonment and coalescence of farms, and intensification of effort and output on the remaining agricultural lands (Wheeler and Black 1954; Black and Brinser 1952). This process is epitomized in the town of Petersham where only a single family continued farming in 1991, but on rented land.

Commencing in the 1930s and continuing after World War II, most of the hill towns of central New England experienced an increase in population based on a steady influx of older couples and commuters deriving their income in neighboring towns or distant cities. This new population is less connected to and less dependent on the land, which is being worked less intensively than at any time in the preceding 250 years. The extensive network of former secondary roads and laneways has been largely abandoned and the nearly continuous forest is aging. Local firewood cutting, low-intensity timber management, high-grading of quality trees, and small-scale clearing of new house lots are the major direct impact on the forest. Commercially, the current population is largely removed from the land.

Land-use Impacts on the Forest

The history of human activity in central New England has resulted in a series of major transformations of the forest vegetation across the landscape and at individual sites. On a township or regional basis, changes have occurred in terms of the extent and pattern of forest cover and the structure and composition of the extant forests.

Forest Cover and Pattern

Information on the pattern and geography of land clearance in New England awaits the painstaking assessment of individual tax and property records, which has been accomplished for only limited areas to date (Raup and Carlson 1941). These data and maps will be essential for addressing a series of important questions: 1) what physical, logistical, and social factors influenced the pattern of land clearance—e.g., were soils, forest type, and agricultural concerns more important than accessibility and transportation,

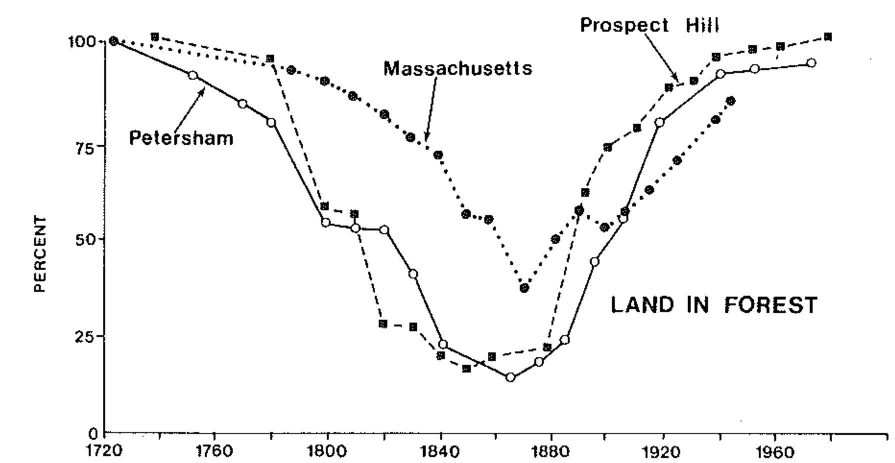

Figure 9.2. Changes in the percentage of the land area covered by forest during the historical period in the state of Massachusetts, town of Petersham, and the Prospect Hill tract of the Harvard Forest. Information is derived from the following sources: Dickson and McAfee (1988), MacConnell (1975), Rane (1908), and Baldwin (1942) for Massachusetts; Raup and Carlson (1941), Anonymous (1959), MacConnell and Niedzwiedz (1974), Cook (1917), and Rane (1908) for Petersham; and from Foster (1991) and Spurr (1950) for Prospect Hill.

or was land clearance an exploratory process determined more by the geography of ownership patterns and haphazard processes; and 2) did clearance involve a general process of expansion of agricultural areas from the center of town and centrally located farms, or did it occur through progressive fragmentation resulting from dispersed activities?

The information that is available suggests that settlers arriving to Petersham in the 1730s found scattered Indian clearings along the broad ridge running north-south through the center of town (Coolidge 1948; see Botts 1934; Bogart 1948; Donahue 1983 for other information on the use of Indian fields and villages in central New England). The availability of Indian sites and the preference by settlers for high ground which is usually less stony, better drained, and more fertile than valleys (Frothingham 1912; Black and Brinser 1952), led to the establishment of Petersham along this ridge. Forest clearance proceeded at a slow though increasing pace through the late 1700s (Fig. 9.2). The average farmer cleared less than 5 acres of land per year and, during this period of low-intensity agriculture, the overall clearing rate for Petersham was approximately 130 acres per year (E.M. Gould, unpublished data). Although the specific pattern of deforestation is unknown, most farms were located along the central ridge and a secondary ridge to the east, and by 1790 only three farms were found west of the village (Coolidge 1948). The general pattern appears to follow that of dispersed settlement and clearing on favorable lands without the development of a compact village center (Clark 1970).

Through the middle of the nineteenth century, the demand for firewood, forest products, and farmland, generated by the increasing population and extensive commercial activity, had a great impact on the forest and landscape. Deforestation rates doubled from those of the eighteenth century (to approximately 260 acres per year; E.M. Gould, unpublished data) as farmers cleared land for pasture and hay. Much of the clearing provided fuelwood for home and industry. The reliance on wood as a source of heat and energy continued through the late 1800s, when coal became readily available (Baldwin 1942; Cook 1961), and was one of the main driving forces altering the remaining forests in the northeast (Williams 1982). In the mid-1840s, the railroads in Massachusetts alone were consuming 54,000 cords of wood per year to fuel trains on 560 miles of track (Cook 1961). Average households were using 15-20 cords per year, which in aggregate consumed more fuel than the charcoal, potash, and other industries combined. By 1850, statewide concern was displayed over forest decimation (Cook 1961) and the Massachusetts General Court issued a recommendation that forest plantations be established in order to address future wood requirements for agriculture, manufacturing, and home fuel (Massachusetts General Court 1846).

For the last 150 years, which encompasses farm abandonment and reforestation, federal and local census records and maps do provide good information on the rate and pattern of forest change for towns like Petersham. A rough map of roads, houses, and woodlands for the township in 1830 depicts the landscape at the height of deforestation and intensive farming activity (Fig. 9.3). The remaining forest areas are indicated as isolated woodlands tens to hundreds of acres in size. Although this map may ignore very small woodlots or recently cut areas, it documents that large forested areas persisted in swamps, rocky and wet lowlands, and steep, ledgy areas. The distribution of stone walls, most of which date from the late 1700s to early 1800s, provides an indicator of farming intensity and, indirectly, of uncleared areas (Fig. 9.3). The densest areas of stonewalls correspond well with the most fertile agricultural soils, whereas areas of poor soils overlap with the woodland areas on the 1830s map. Remaining woodlots were repeatedly cut and were often grazed to the point of being wooded pasture (Cline et al. 1938).

Reforestation, occurring upon the neglect or abandonment of pasture lands, commenced as early as the 1840s in the town of Petersham, and somewhat later across central New England (Fig. 9.2). Abandonment rates increased sharply through the late 1800s, when nearly 300 acres were reforested annually, slowed from 1900-1940 (approximately 35 acres per year), and have been decreasing since that time as nearly the entire township has become covered with forest (MacConnell and Niedzwiedz 1974; E.M. Gould, unpublished data; Fig. 9.4). The spatial pattern of reforestation has involved the gradual expansion of individual woodlots and progressive coalescence of adjoining forest lands (Fig. 9.3). The driving factor behind this process is apparently that the abandonment of agricultural

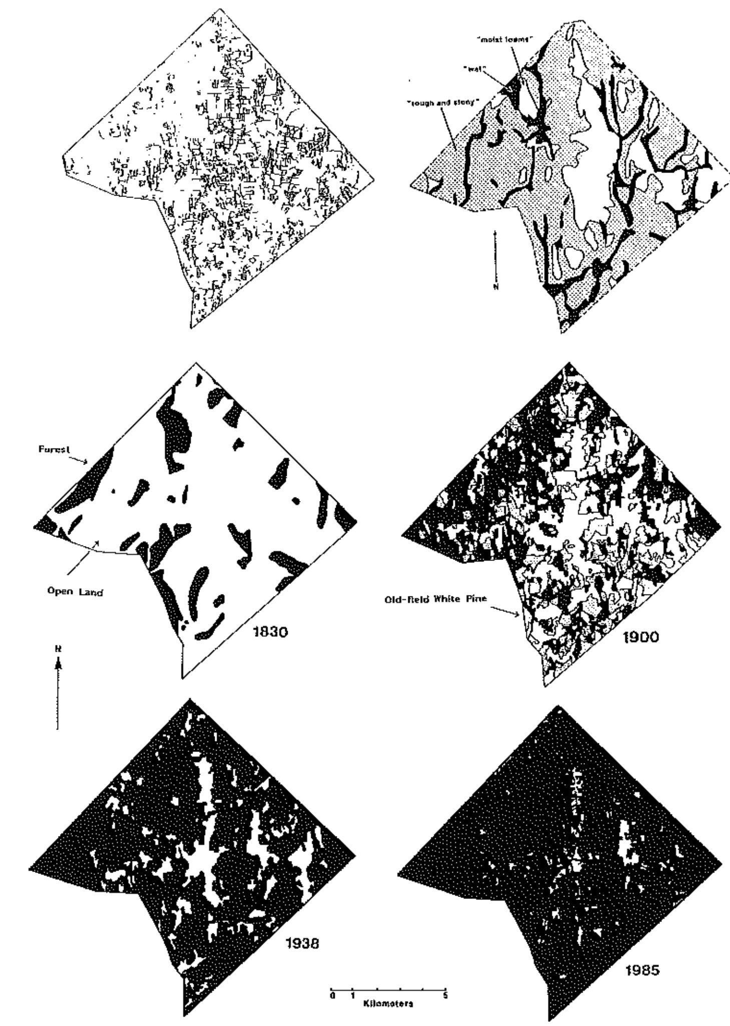

Figure 9.3. The township of Petersham, Massachusetts, depicting agricultural suitability (white, shaded, and black), stonewalls, and forest cover for the periods 1830, 1900, 1938, and 1985. In the forest map for 1900, shaded areas indicate agricultural land that was abandoned between 1870 and 1900 that developed forest of white pine. Stone walls and agricultural land during the abandonment period (mid 1800s to present) are concentrated in areas of more productive soil. Maps are compiled from the atlas of Worcester County (1830), Worcester County Land Use Project (1930), and analysis of aerial photographs for 1985.

lands proceeded across marginal areas in valleys, slopes, and poorly drained sites adjacent to existing woodlands, and at the back part of individual farm properties. Thus, reforestation appears to progress upslope from steep or poorly drained areas to lands of gentle, upland relief, from back lots toward roadways, and from poorer to better agricultural lands. The overall

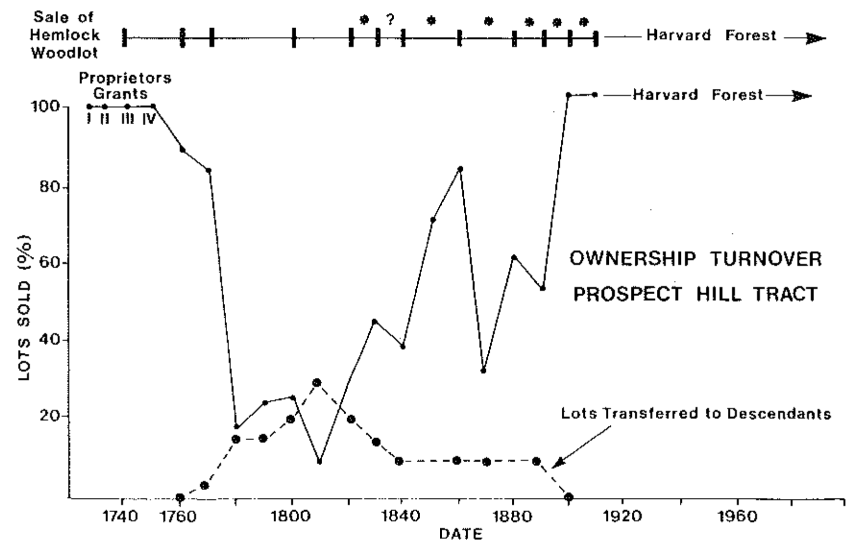

Figure 9.4 Historical changes in the rate of property sales on the Prospect Hill tract of the Harvard Forest, in the northern part of the town of Petersham. Property sales declined through the period of commercial agriculture (1790-1850) as farmers worked their land intensively and passed it on to descendants. Land sales increased with farm abandonment, land speculation, and logging activities in the second half of the nineteenth century.

pattern is a contraction of the remaining open land, concentrating on the most productive ridge-top sites.

The pattern of progressive reforestation can be seen in the distribution of the successional, old-field white pine stands in the 1900 landscape (Fig. 9.3). Pine stands are generally situated between older forests established at an earlier date, and open fields in ridge-top locations. Open fields persisting in 1990 were small, often isolated from one another, and located along the major north-south and east-west roads bisecting the town center.

Compositional and Structural Changes in the Forests

Pre-settlement Environment and Forest Composition

Based on palynological studies and reconstructions of individual forest histories, it appears that stand-regenerating and broad-scale disturbance processes, such as intense fire or catastrophic windstorms, occurred relatively infrequently in the pre-settlement landscape of central New England (Stephens 1955; Foster and Zebryk 1993). The overall abundance of charcoal in lake and swamp sediments in this region is low (P. Schoonmaker, T. Zebryk, D. Gaudreau, pers. comm.) and suggests an intermediate occurrence of fire between that of the frequently burned coastal regions of eastern Massachusetts (Patterson and Backman 1988; Winkler 1985) and locations in the western hills of the state where no fires have been detected in the previous 1000 years (Backman 1984). Detailed investigation of one lowland site at the Harvard Forest recorded eight fires in the last 7800 years, indicating that fire is an important though infrequent disturbance (Foster and Zebryk 1993).

Evaluation of the disturbance regime of windstorms relies on the single study by Stephens (1955), although an assessment of the impact of historical storms to the New England landscape is in progress. (E. Boose, pers. comm.). Stephens' study indicated that there were major storms in the 1500s and early 1600s as well as the historical storms in 1788, 1815, and 1938 (Smith 1946). These storms would have had highly heterogeneous impacts on the landscape, depending on their intensity, wind direction, and the interplay of landscape physiography and structural and compositional characteristics of the vegetation (Foster and Boose 1992).

Human activity, notably Indian clearing and possibly burning for fields and villages, created local openings in the forest. However, these impacts would have been minor on a regional scale, for example, not showing up on regional pollen diagrams (Patterson and Sassaman 1988). Structurally, therefore, the pre-settlement forest landscape was comprised largely of older growth and uneven-aged stands with occasional openings or even-aged patches resulting from natural and human disturbance. A combination of gap dynamics and patch formation, resulting from chronic background mortality and broader-scale damage, would create a mosaic landscape structure.

Three sources of information provide an insight on the composition of the pre-settlement forest. Analysis of observations and relative abundance data contained in the descriptions by Peter Whitney (1793) of the 62 townships in Worcester County describe phytogeographical trends that are indistinguishable from those of today. Forest vegetation types corresponding to central hardwoods, transition hardwoods, and northern hardwoods (cf. Westveld 1956) are arranged on a southeast to northwest axis across Worcester County and follow the elevational and latitudinal gradient (Fig. 9.5; Foster 1992; Raup and Carlson 1941). Central hardwood communities were dominated by hickory (*Carya*) and oak (*Quercus*) species, chestnut (*Castanea dentata*), and white pine. Transition hardwood forests included these taxa (with less hickory) plus greater amounts of red maple (*Acer rubrum*), birch (*Betula* spp.), ash (*Fraxinus americana*), beech (*Fagus grandifolia*), hemlock (*Tsuga canadensis*), and pitch pine (*Pinus rigida*). In the few northern towns represented by northern hardwood forest, hickory,

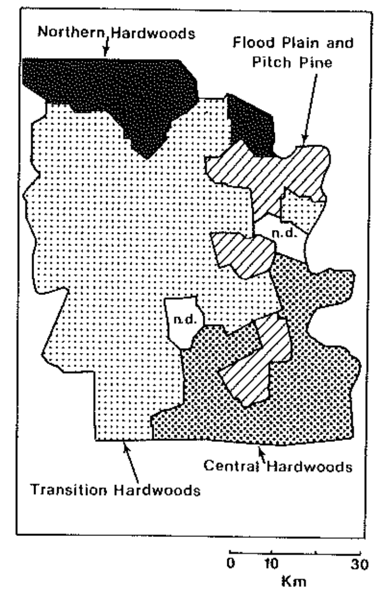

Figure 9.5. Map of Worcester County, Massachusetts, depicting the major forest vegetation zones as independently derived from an analysis of descriptions by Peter Whitney (1793) for the mid eighteenth century. Modified from Foster (1992). The Flood Plain and Pitch Pine forest is a variant of the Transition Hardwood Forest. Compare this historical map with the modern vegetation of Worcester County outlined in the New England map by Westveld (1956) in Fig. 9.1.

chestnut, and pitch pine were unimportant, and sugar maple (*Acer saccharum*), yellow birch (*Betula leutea*), and white birch (*B. papyrifera*) were common. The forests of Petersham were described by Whitney as dominated by oak across the uplands with birch, beech, maple, ash, elm (*Ulmus* spp.), and hemlock common in lowlands. Interestingly, he described chestnut as a species that was increasing on the uplands as a result of settlement activities.

Corroboration of Whitney's description of Petersham is provided by witness tree data collected during the laying out of original lot boundaries in the town (G. Whitney, unpublished data). Species comprising the 384 trees sampled include oak (32%, mixture of black [*Q. velutina*], white [*Q. alba*], and red [*Q. borealis*] oak), pine (21%, primarily, white pine), chestnut (9%), maple (9%), and hemlock (9%) with lesser amounts of beech, birch, ash, poplar (*Populus spp.*), and hickory.

Finally, pollen data from a lowland swamp in the center of the Harvard Forest provide information on the composition of the regional vegetation (Fig. 9.6; Zebryk 1991). Pre-settlement sediments contain high levels of beech, pine, oak, birch, and hemlock with lesser amounts of red maple, sugar maple, and chestnut. The three sources of information concerning

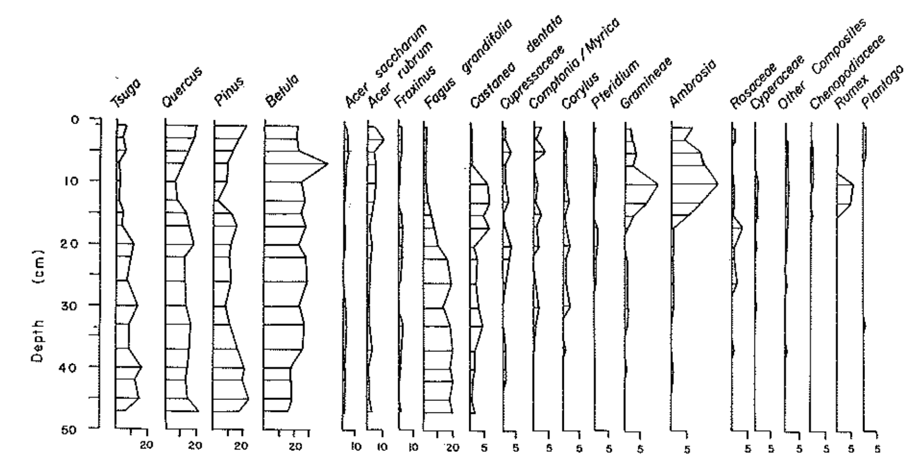

Figure 9.6. Pollen diagram from the Black Gum Swamp in the Harvard Forest (Petersham, Massachusetts) depicting changes in the regional vegetation of central New England. The pre-settlement vegetation is represented by the lower portion of the diagram, initial settlement activity (ca. 1750) is indicated by the rise in *Gramineae* and weed species (*Ambrosia, Rosaceae, Compositea*) at 30-32 cm, and the chestnut blight (ca. 1910-15) occurs between 7 and 10 cm. Data from Zebryk (1991) and modified from Foster et al. (1992).

these early forests thereby suggest that the broad vegetational distinction of this area as transitional hardwood forest was applicable (cf. Raup and Carlson 1941) and that the landscape may have been comprised of oak, chestnut, and pine forests on the uplands, forests of beech, birch, maple, and ash with hemlock in the valleys and lowlands, and swamps dominated by red maple or by spruce (*Picea*), larch (*Larix*), and black ash (*Fraxinus nigra*). Beech, sugar maple, chestnut, and hemlock were more abundant in early forests than at present (Fig. 9.6; Foster and Zebryk 1993).

Post-settlement Forests

With the arrival of European settlers, structural changes in these forests were initiated with progressive forest clearance accompanied by selective logging of specific size categories and species of tree. Grazing of livestock in forests and the overgrowth of neglected pastures led to the development of a new category of vegetation—the wooded pasture or brush pasture, much of which was included in census records under the large category of unimproved land (G. Whitney, pers. comm.). Due to grazing and repeated

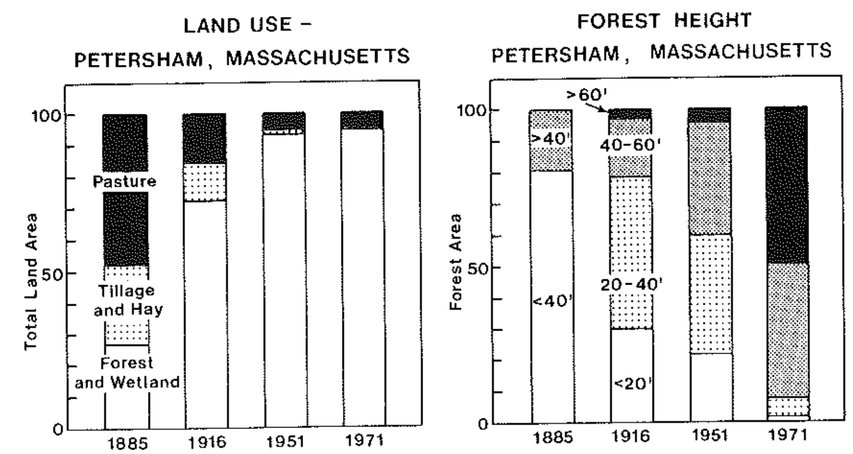

Figure 9.7. Historical trends in land-use activity and forest structure for the town of Petersham, Massachusetts, during the period of farm abandonment and reforestation. Note that the 1885 data for height structure depicts forty-foot classes, whereas the later years depict twenty-foot height classes. 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).

cutting, woodlots and forest remnants must have resembled sprout woods rather than the original older growth forests (Barraclough 1949; Donahue 1983; see Russell, Chapter 8, this volume, for similar conclusions in a different region).

Essentially, no historical records describe the composition of the forests through the mid nineteenth century with the exception of occasional references in journals, town histories, and letters. Thus, we have no details on the spatial arrangement and specific structural and compositional characteristics of this changing vegetation. However, the palynological record depicts the major regional changes which include a striking decrease in northern hardwood species (beech and sugar maple), hemlock, pine, and oak and a sharp increase in chestnut (Fig. 9.6). Specific agricultural activities reflected in the pollen spectra include hay production (*Gramineae*), grazing (*Comptonia, Pteridium, Rosaceae*), and tilled and marginal lands (*Chenopodiaceae*, *Ambrosia*, *Rumex*, *and Plantago*).

Land-use practices since the mid-1800s have produced a mosaic of essentially even-aged patches of forest (Fisher and Terry 1920; Fig. 9.7). Although the process of land abandonment generally occurred through neglect often accompanied by grazing, the constituents of the resulting forest canopy generally dated to within 20 years of abandonment (Fisher 1931). The establishment of even-aged white pines in former fields initiated a lumber industry in the 1870s that operated through the use of portable sawmills and a practice of clear-cutting (Ahern 1929; Fisher 1931; Cline et al. 1938). Advanced regeneration of hardwoods below the pines was generally cut or

damaged during logging or was burned with the slash. Thus, an even-aged forest of hardwood sprout generally followed the pines (Thoreau 1962). Overall, the development of even-aged forests through the early part of the twentieth century can be ascribed to these two major processes (Barraclough 1949): 1) repeated culling of woodlands; and 2) reversion of agricultural land to woodland.

The 1938 hurricane added the latest broad-scale structuring to the forest landscape. On exposed sites, conifer stands over 30 years old were completely windthrown (Black and Brinser 1952) and hardwoods, though less susceptible, were severely damaged (Foster 1988; Foster and Boose 1992). Across Petersham, approximately 50% of the forest suffered extensive windthrow. Salvage operations throughout New England involved clear-cutting of severely damaged areas and burning of slash, thereby accentuating the conversion of conifer stands to even-aged sprout hardwoods (NETSA 1943).

Forestry practices since the 1930s have progressively emphasized a combination of patch cutting and selective removal. Thus, through forest development, small-scale natural disturbance, and reduced harvesting intensity, the forests are aging and becoming more diverse in terms of within-and-between stand age-structure (Fig. 9.6; MacConnell and Niedzwiedz 1974). The predominant forests in the landscape, however, are 50-80 years old with the majority post-dating the 1938 hurricane.

Overall through this century, major changes in the composition of forest vegetation reflect the dominant influence of cutting practices and the 1938 hurricane, progressive aging of the forest and the introduction of major pathogens (Cline et al. 1938). Timber harvesting and the selective impact of the hurricane have resulted in a declining importance of white pine. Other species that seeded into fields and abandoned areas, such as gray birch (*Betula populifolia*), aspen (*Populus grandidentata*), pin cherry (*Prunus pensylvanica*), and red maple (Lutz 1928), peaked in abundance in the first part of the century and have decreased as the forest has aged. Meanwhile, chestnut, which appears to be the species that increased most prolifically through the agricultural and logging period, has been converted to an understory sprout sapling by the chestnut blight (Paillet 1982). The recent trend in forest composition has been for a progressive increase in longer-lived and shade tolerant hardwoods (e.g., sugar maple, beech, yellow birch, and red oak) and especially hemlock (Foster 1992). Large, older growth hemlock are primarily restricted to areas that remained wooded throughout the settlement period. However, hemlock is common in understory situations and is gradually increasing in abundance across the landscape.

Detailed History of a Woodlot Forest

In order to assess the magnitude of transformation of the forest vegetation resulting from human activity, it is instructive to examine the composition and dynamics of the remnant forests that persisted through the settlement period. Many of these forests are currently dominated by hemlock, pine, and northern hardwood species 75-125 years old. As a result of the relatively large size of the individual trees, the presence of typical "climax" species (hemlock, beech, red oak, yellow birch; cf. Nichols 1913), and the absence of evidence of recent human activities, certain of these stands appear to provide possible examples of the original forest cover of the area. In fact, considerable attention has been given to such forests in the past in an effort to understand the pre-settlement vegetation (Raup and Carlson 1941; Spurr 1956).

One such forest in northern Petersham was recently examined using paleo-ecological and reconstruction techniques in order to describe the dynamics, structure, and composition of the original vegetation, and to follow its history through the settlement period described above. The forest is a lowland stand of hemlock with white pine, red spruce, red oak, beech, and red maple. The area was part of an extensive woodlot that appears on the 1830 map of forests in Petersham and it occupies the central part of the Prospect Hill tract of the Harvard Forest (Foster et al. 1992).

Palynological investigation of sediments in a small hollow in the center of the stand indicate that over the past 7000 years the local vegetation has been dominated by hemlock, pine, and hardwoods (Fig. 9.8, T. Zebryk, unpublished data; Foster and Zebryk 1993). Spruce increased in abundance approximately 2000 years ago and chestnut migrated into the region and became a component of the local vegetation approximately 3000 years ago.

However, despite the long-term dominance of the site by a small number of species, the vegetation has undergone dynamic changes in response to fire (7650, 6650, 6150, 4700, 1900 B.P.), the hemlock decline (4700 B.P.) and human activity (250 B.P.). Following each of the disturbance episodes, the abundance of hemlock and associated species has declined and then recovered (Fig. 9.8). The nature of the successional sequence preceding this recovery has depended strongly on the type of disturbance and the pool of available species.

From 8000-2000 B.P., fire (and the hemlock decline which was coincident with a fire at 4700 B.P.) initiated a decline in hemlock and northern hardwoods, whereas birch, oak, and pine increased for a 300-1000 year interval after the disturbance. Following the arrival of chestnut to the region, it became a minor component of the forest and then increased prolifically after a fire at 1900 B.P. Chestnut was able to replace pine, birch, and oak as a successional component following disturbance, due to its tremendous sprouting capacity and growth rate. In the period extending

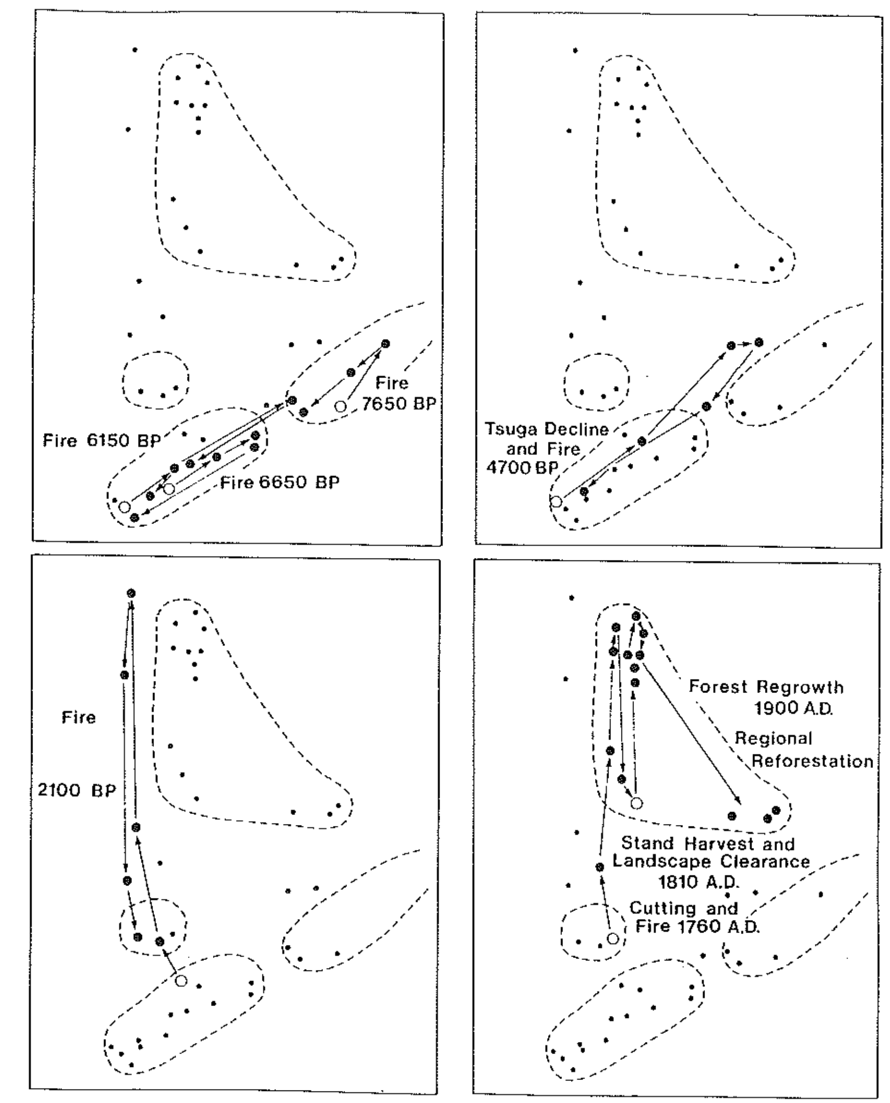

Figure 9.8. Position on the first two DECORANA axes of pollen stratigraphic samples for the Hemlock Woodlot in the Prospect Hill tract of the Harvard Forest. Enclosed areas contain samples representative of major pollen zones and inferred vegetation types. Areas indicate the direction of sample movement through time from oldest (>9,000 B.P.) to modern. Progressive change in sample positions from 9,000-7,500 B.P. reflects species migration in response to environmental change (A). The period 7500-200 years marks a time of relatively stable vegetation of hemlock and hardwoods (B), with chestnut and spruce increasing approximately 2000 B.P. (C). The distinctive position of the post-settlement samples is indicative of the unique assemblages of pollen deposited at this time and is strongly controlled by the presence of native and introduced weed species (D). Modified from Foster and Zebryk (1992).

300-500 years after the fire, hemlock, beech, and sugar maple returned essentially to their pre-disturbance levels.

During the settlement period, the stand was affected directly by repeated cutting; the palynological record documents changes reflecting these activities, regional deforestation, and extensive agriculture. During historical times the forest was subjected to the following disturbance: cutting in 1765, 1790, 1830, 1870, 1893, 1900, 1913, 1940, and 1957; wind damage in 1815, 1921, 1938, and 1941; and the chestnut blight in 1914-1920 (Foster et al. 1992). Apparent clearcuts occurred in 1765 and 1870, whereas the remainder of the cutting probably involved the removal of firewood or small logs, through forest thinning. The forest woodlot was owned in common with a tannery from 1839 onward, and it is likely that hemlock, chestnut, and possibly oak were used as a source of tannic acid.

Vegetationally the stand was transformed by this human activity. Former dominant tree species in the forest—beech, hemlock, sugar maple—essentially disappeared from the very local pollen record, whereas oak, pine, and birch declined greatly. Chestnut increased prolifically, reaching maximum levels of 60-80% of the pollen assemblage, which suggests the conversion of the stand from northern hardwoods-hemlock forest to a stand of sprout hardwoods. Chestnut has an extraordinarily rapid growth rate and sprouts prolifically and, thus, is capable of dominating stands following cutting (Paillet 1982). This transformation of the hemlock woodlot provides some indication of the process whereby chestnut increased in the post-settlement landscape throughout southern New England.

Repeated cutting for poles, cordwood, and possibly tanning materials evidently maintained the high level of chestnut in this forest through the early 1900s. Shortly following acquisition of the land by the Harvard Forest, there was a shift to reduced logging activity and the chestnut blight in 1913. The resulting decline of chestnut allowed the increase of first birch, and then oak, hemlock, pine, spruce, and red maple. Sugar maple and beech never recovered to their former abundance.

A number of major conclusions may be drawn from the intensive study of this one site. It is clear that during pre-settlement times that the stand was dynamic over periods of hundreds of years in response to natural disturbance, especially fire. The post-disturbance vegetational sequence was dependent on the pool of available species; for example, the successional sequence changed greatly upon the immigration of chestnut. In all cases the species assemblage reverted largely to that which was present before the disturbance. Settlement activities generated a similar initial response in the vegetation as chestnut dominated the pollen rain. However, the repeated cutting of the stand and the broad-scale deforestation of the landscape created conditions that produced a unique vegetation in which hemlock is now abundant and beech and sugar maple have been essentially eliminated. Thus, as the modern landscape has become reforested and the hemlock stand is aging, the vegetation is developing along a trajectory that is distinct from any that has occurred in the past.

Conclusion

The examination of the woodlot stand at the Harvard Forest provides convincing evidence of the long-term dynamics of forests in this region and the different quality of the disturbance processes resulting from human activity. During the course of the last 300 years, the stand has been modified in long-lasting ways that differ considerably from the consequences of repeated fires and pathogen effects during pre-settlement time. Elsewhere in the landscape the transformations were even more severe; entire forests were replaced by open fields that were grazed, cut, or tilled. The entire pre-settlement flora including buried seed populations was eradicated locally from these sites. It is quite clear that although the major geographic trends in forest vegetation still hold, that the individual forests, their composition, structure, and arrangement in the landscape, are distinctly different from the primary woods, let alone the natural vegetation (Whitney 1992; Whitney and Foster 1990).

The post-settlement changes in this landscape have involved shifts in the extent and pattern of the forests, and apparent constant alteration in the structure and composition characteristics of the extant stands at any given time. These forest dynamics were driven by human activities embedded in an ever-changing cultural context. The forest picture has not been static because the human forces were and are continually changing.

Many questions remain. There is great uncertainty regarding the nature and arrangement of the pre-settlement forests and the influence of aboriginal populations and natural disturbance processes on them. The extent of change in forest cover throughout the post-settlement period is well-known but we know little about loss of species, changes in community complexity, and alterations in the relative importance of species. Of particular interest is the manner in which changes in community and ecosystem characteristics of these forests may have long-lasting impacts in their functional aspects. We know that the aggregate changes that have occurred affect the manner in which broad-scale and local disturbance processes operate (Foster and Boose 1992; Sipe 1990). These changes may have very important consequences for our interpretation of fundamental ecological attributes as well as management considerations (Metropolitan District Commission 1991). Preliminary studies suggest that land-use changes may have long-lasting impacts on the way in which modern forest soils process organic matter and nitrogen compounds (J. Aber, pers. comm.). This, in turn, could have far-reaching impacts on forest productivity, biosphere-atmosphere exchange, and ultimately on the global atmosphere (Steudler et al. 1989; Aber et al. 1989). To sort out these questions will require continual interdisciplinary efforts among social, physical, and biological scientists.

Recommended Readings

Aber, J., K. Nadelhoffer, P. Steudler, and J. Melillo. (1989). Nitrogen saturation in northern forest ecosystems. *BioScience* 39:378-386.

Cronon, W. (1983). *Changes in the Land. Indians, Colonists, and the Ecology of New England*. Hill and Wang, New York.

Merchant, C. (1989). *Ecological Revolutions—Nature, Gender, and Science in New England*. University of North Carolina Press, Chapel Hill.

Patterson, W.A. and A.E. Backman. (1988). Fire and disease history of forests. In: B. Huntley and T. Webb III, eds. *Vegetation History*, pp. 603-622. Kluwer, The Hague.

Raup, H.M. (1966). The view from John Sanderson's farm. *Forest Hist.* 10:2-11.