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A PERSPECTIVE FROM THE COLUMBIAN ENCOUNTER
GLOBAL LAND USE CHANGE

Chapter 10

Vegetation Change in New England
Land-Use History and Four Hundred Years of

David Foster

The opaline white vegetation of New England? Trees, of course.

H. M. Ranger

Introduction
vegetation effectively obscures the evidence of the landscape transformations that have occurred as a result of intensive agricultural activity. In even larger portions of the developing world deforestation and forest ecosystem modification are presently occurring at a prolific rate. Thus, a major objective of this review of changes in the New England landscape is to provide information relevant to a general understanding of human impacts on forested regions.

A final objective is to focus in more closely on the social causes of the changes that have occurred in New England forests. Information on the economic, technological, and historical factors underlying human activity provides a context for understanding the changing pressures on forests in this region. Ultimately, it is hoped that a broader understanding of the dynamic changes in the landscape will provide a strong basis for guiding decisions on future research, conservation priorities and management activities of this forested area.

In reviewing the natural forest dynamics, human history and landscape transformation of New England this paper focuses on the states of Connecticut, Rhode Island, Massachusetts, Vermont and New Hampshire as they share many similarities in physical features, biological characteristics and human history. It excludes much of Maine, which differs greatly in terms of forest conditions and land-use activity. Most of the discussion deals with the upland heart of the region where most of the forested area occurs. However, the coastal and riverine lowlands were important regions of commercial enterprise and population density; activities in the lowland centers were inextricably interwoven with the transformations in the upland landscape (Cronon, 1991). These connections are commented on in this paper where relevant.

Following a brief review of regional characteristics, insights from paleoecological studies are utilized to highlight the dynamic nature of the precolonial vegetation in response to natural environmental change and disturbance. A detailed review of the history of colonial settlement and development of the New England landscape is then presented to provide the social context for understanding the resulting vegetational changes. Finally, the vegetational, faunal and ecosystem consequences of this human land use are outlined. This background is used to discuss potential future changes and areas for further study.

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 east from the Atlantic Ocean. Physiographically the region consists of seven broad areas, the coastal lowlands, inland uplands, the Connecticut River valley, the Champlain valley and the White Mountains, Green Mountains, and Taconic Mountains (Figure 1). These regions differ in bedrock geology, as well as elevation and relief; however, with major exceptions in the Connecticut River valley and Taconic range the geological substrate is comprised of acidic, relatively nutrient-poor material. The entire region was glaciated until approximately 10-13 thousand years ago. Variation in the depth and texture of surficial materials is the result of local glacial geomorphology. 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 1000 mm and is evenly distributed throughout the year. Summer temperatures average 22°C (July) whereas winter averages drop to 4°C (January) in inland locations. Regional differences in growing season length exceed three weeks between southern coastal and northern locations. Within the region the broad valley of the Connecticut River provides a distinct environment due to its low elevation and the predominance of broad, level areas of glacial lake sediment, sandy deltaic material and floodplain deposits.

The regional vegetation changes latitudinally with local variation due to elevation in the Connecticut Valley and northern mountains (Figure 2). Northern hardwoods-conifer forest covers much of Vermont and New Hampshire, extending southward along the White and Green Mountains 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 (Betula populifolia) and hickory (Carya ovata, C. cordiformis) along with red maple and
community occurs across central Massachusetts, up the Connecticut River valley and through eastern New Hampshire. A distinctive vegetation of pitch pine (*Pinus rigida*) and oak (*Quercus ilicifolia, Q. stellata*) species occurs on sandy soils across Cape Cod and inland on outwash deposits.

**Dynamics of the precolonial landscape**

Any serious attempt to evaluate the role of European settlers in transforming the landscape of North America must establish the range of environmental conditions and dynamics of the vegetation during "presettlement times," when aboriginal peoples and natural processes shaped the landscape. Although the earliest historical accounts contain some insight on this period, they provide only a snapshot view that may be biased by the background or motivations of the recorder (Russell, 1980; Cronon, 1983; Crosby, 1986). In contrast, paleoecological studies provide a lengthy temporal perspective for evaluating vegetation and environmental conditions in a consistent manner from prehistorical through modern times. Specific topics addressed by the paleoecological record that pertain to the understanding of the impact of European settlement on the region include: the rate of presettlement ecosystem change, the role of non-climatic factors (e.g., natural and aboriginal disturbance processes) in altering terrestrial and aquatic environments, and the evolutionary context for the organization of plant and animal communities.

The paleoecological record from New England supports the viewpoint of environment and vegetation as dynamic on geological and ecological time scales (Watts, 1973; Davis, 1986; Hunter et al., 1988; Huntley and Webb, 1989). Major environmental factors including climate have changed continuously in the recent past, though at variable rates. Coupled with natural disturbance processes, this dynamic environment has generated shifts in the overall ranges of many plants and animals and changes in the composition and structure of forest communities. These observations support the notion of plant and animal communities as aggregations of individualistic species responding to unique combinations of climatic, edaphic, biotic and historical factors (Fisher, 1933; Wright, 1977).

In New England vegetation and environment have varied continuously in time and space since the last glacial period (Figure 3). Following great changes in precipitation, temperature, and wind conditions in the millenia after deglaciation, temperate climatic conditions broadly similar to the present were established between 8-10 thousand years before present (B.P.). Thus the major modern forest zonations (e.g., conifer forest at

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**Figure 3.** Pollen diagram from the Black Gum Swamp at the Harvard Forest in central Massachusetts depicting the major vegetational changes in the vegetation over the past 12,000 years. Tundra communities were replaced by boreal forest dominated by spruce until approximately 9200 years B.P. when pine and other tree species became important. Changes in relative abundance of species resulted from climate change, species migrations, disease (*Tsuga*) and fire until 250-300 years B.P. when European settlement resulted in major deforestation and the increase in agricultural weeds, herbs and successional species. Note vertical scale change at 250 years B.P. Modified from Foster and Zebryk (1993).
Characteristics of forest (Flather, 1930; Childe and Spur, 1942; Davis, 1942).

The distribution of these forest types is determined by the local topography and soil conditions, as well as the availability of water and nutrients. The forest types are characterized by their unique vegetation and wildlife communities, which provide important resources for human use.}

In New England, the forest types are categorized into three main groups: eastern deciduous forest, western coniferous forest, and mixed forest. Each group has its own distinctive characteristics and is found in different areas of the region.

The eastern deciduous forest is characterized by trees such as maple, oak, and pine, which produce a wide variety of fruits and nuts. This forest type is found in the eastern part of New England, where the climate is mild and the soil is rich in nutrients.

The western coniferous forest is characterized by trees such as ponderosa pine and aspen, which are adapted to the drier climate of the western part of New England. This forest type is found in the western part of the region, where the climate is warmer and the soil is not as fertile.

The mixed forest is characterized by a combination of deciduous and coniferous trees, which provide a diverse range of resources. This forest type is found in the transition zone between the eastern deciduous and western coniferous forests, where the climate and soil conditions are intermediate.

The forest types of New England are important for their biodiversity and ecological services, such as water filtration and regulation, carbon sequestration, and habitat for wildlife. The conservation and management of these forest types is crucial for maintaining their ecological integrity and providing benefits to human communities.
regions to the north and from major river basins into highland areas (Figure 5). Along the latitudinal gradient there is a shift from a partial reliance on agriculture to primarily hunting and gathering (Patterson and Sassaman, 1988). The hilly and mountainous regions of interior Vermont and New Hampshire were probably subjected to the least impact by Indian land use.

Agriculture came very late to the eastern woodland Indians and may have involved short fallow or semipermanent cultivation that generated a mosaic pattern of fields, abandoned garden and village sites, and intact forest (Doolittle, 1992). Although early historical accounts abound with descriptions of local forest clearance around Indian villages, there is little evidence that aboriginal activity exerted an impact on the broad-scale pattern of vegetation as would have occurred for example through extensive slash-and-burn agriculture (Burden et al., 1986a/b; McAndrews, 1988; Patterson and Sassaman, 1988). To date there is no conclusive paleoecological record of Indian modification of the New England forest landscape. Even in coastal regions where Indian population densities were presumably highest there is a general absence of the pollen of cultivated plants or fluctuations in weedy and early successional species that would suggest extensive forest clearance and farming (Winkler, 1985; Dunwiddie, 1989).

Wind Damage and Pathogens

Wind damage and pathogens are natural disturbance processes of regional importance in the precolonial landscape. Soil evidence of the uprooting of forest trees extends back nearly 1000 years and documents the ubiquity of wind damage in northeastern forests (Fisher, 1933; Stephens, 1955; Lyford and MacClean, 1966). The relative importance of different types of wind damage apparently varies across New England, with downbursts and northwesterly storms more important in northern New England and tropical storms increasing to the south (Hosier, 1969; Bormann and Likens, 1979; Foster, 1988 a/b). Historical analysis indicates that hurricanes may occur with a frequency of one major storm every 50-100 years and a decreasing gradient of importance across New England from southeast to northwest (Figure 6; Foster and Boone, 1992; Boone et al., 1993). General considerations of the meteorological characteristics of tropical storms suggest that catastrophic storms may be restricted to pathways similar to the hurricanes in 1815 and 1938, which would constrain the strongest winds to those coming from the south and east and going in a northern direction (Foster and Boone, 1992). Thus, there may exist some predictability in landscape-level exposure to tropical winds, with level, south- and east-facing slopes being most exposed and steep northwesterly slopes protected (Boone et al., 1993). The absence of specific stratigraphic markers associated with wind

Figure 4. Location and average charcoal abundance of sedimentary fire-history studies in the northeastern United States. There is a general trend of increasing precolonial charcoal abundance from inland and northern sites to coastal and southern sites. Most sites exhibit an increase in charcoal abundance following European settlement. Modified from Patterson and Backman (1988) and Patterson and Sassaman (1988).

<table>
<thead>
<tr>
<th>Pond/Lake</th>
<th>Location</th>
<th>Average Precolonial</th>
<th>Average Postcolonial</th>
<th>Ratio Post/Pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larim</td>
<td>Massachusetts (central-inland)</td>
<td>27.5</td>
<td>190.5</td>
<td>6.9</td>
</tr>
<tr>
<td>Basin 1</td>
<td>Maine (north-inland)</td>
<td>80.9</td>
<td>385.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Conrey 1</td>
<td>Maine (north-middle)</td>
<td>38.7</td>
<td>291.1</td>
<td>7.5</td>
</tr>
<tr>
<td>The Bowl 1</td>
<td>Maine (north-central)</td>
<td>123.4</td>
<td>390.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Sargent Mountain 1</td>
<td>Maine (north-central)</td>
<td>133.1</td>
<td>161.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Long 1</td>
<td>Maine (north-coastal)</td>
<td>151.9</td>
<td>326.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Deep 1</td>
<td>New York (south-east)</td>
<td>650.1</td>
<td>1040.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Duck 1</td>
<td>Massachusetts (central-east)</td>
<td>250.7</td>
<td>160.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Charge 1</td>
<td>Massachusetts (central-east)</td>
<td>713.9</td>
<td>2895.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Wigwam 1</td>
<td>Massachusetts (central-east)</td>
<td>580.7</td>
<td>968.2</td>
<td>1.7</td>
</tr>
</tbody>
</table>

1 Data from Winkler (1982) as modified from Swain (1981).  
2 Values are approximately 50% low due to problems discriminating small particles from pyrite.
Figure 6. Paths of the major hurricanes that have impacted New England from 1600 to present. The damage inflicted on forests in the region by the 1598 hurricane (e) was moderate to severe, and more than 600 lives were lost. The 1635 hurricane (f) was the most severe hurricane to affect the region in recorded history. Approximately 3 billion board feet of timber were windthrown by the storm, and damage costs exceeded $100 million.

From Prescott and Sissingh (1958).

Figure 5. Area of concentrated European settlement in southern New England during the Late Woodland Period (A.D. 1000-1600) (modified from European settlement patterns). The coastal area and the larger islands were the preferred sites for European settlement.
damage will make it difficult to verify these broad conclusions over presettlement times using palaeoecological techniques (Foster and Zebryk, 1993).

For pathogens there is but a single putative presettlement event, but it was of broad-scale and long-lasting importance. Starting approximately 4800 BP there occurred a major and apparently synchronous decline of eastern hemlock across its range (see Figure 3; Davis, 1981a; Webb 1988). The rapidity of the decline, its similarity to the impact of the chestnut blight, and its apparent independence from climate change or decline in other species, lead Davis (1981; Allison et al. 1986) to identify it as the result of a pathogen. One possible candidate is an insect like the eastern hemlock looper, which is currently decimating kilometer-wide areas of hemlock across central Massachusetts.

Hemlock persisted during this period in low population levels throughout its range (Davis, 1981b; Allison et al., 1986; Foster and Zebryk, 1993) and recovered to approximately its former abundance in 1000-1500 years, evidently through the evolution of resistance to the pathogen. A number of important observations concerning forest response to pathogens can be drawn from this event: (1) the reorganization of communities after this event differed regionally, and took 400-500 years; (2) hemlock eventually recovered to its original abundance in some locations but in general was reduced somewhat due to the importance of new species that had immigrated during the interim, or to slight changes in environmental conditions; and (3) significant ecosystem-level changes occurred at many sites, in terms of altered soil characteristics and chemistry, changes in stream water and aquatic processes, and varied forest structure (Whitehead, 1979; Davis, 1985; Ford, 1990; Whitehead and Jackson, 1990).

**Insights from the Precolonial Landscape for Understanding Modern Ecosystems**

Major lessons from palaeoecological studies that pertain to the understanding of the environmental setting encountered by European colonists and their impact upon these ecosystems are manifold: (1) both the environment and the biotic communities arrayed across the New England landscape have a dynamic presettlement history (Fisher, 1933); on an ecological time-scale forest communities never reached a long-term equilibrium; (2) once perturbed by natural disturbance or climate change vegetational adjustment is long-lasting, e.g. on the order of 400-500 years (Foster and Zebryk, 1993); (3) most of the human and natural disturbance processes in pre-colonial times were infrequent and distributed in a geographically uneven pattern controlled by climate, physiography and possibly the distribution of aboriginal populations; and (4) the forest communities encountered upon European settlement had been established for only approximately 2-3 thousand years and were comprised of species that evolved under rather dynamic edaphic and environmental conditions (Spear, 1989; Whitehead and Jackson, 1990).

**European Settlement and Expansion in New England**

From well-established coastal settlements, European colonists expanded northward and inland through New England at an uneven pace (Figure 7; Monroe et al., 1980; Donahue, 1983). Due to the absolute reliance of early settlers on agriculture, topography exerted a strong influence on migration and settlement patterns. Initial expansion in Connecticut occurred along Long Island Sound (Atlantic Ocean), and northward along the river valleys of the Thames, Connecticut and Housatonic. This was followed much later by gradual dispersion into the northwestern and northeastern highlands. After the end of the Queen Anne's War (1713) settlement progressed west and northward across Massachusetts and in 1725 the General Court of Massachusetts commenced using land grants to pay debts, especially for military service (Clark, 1983); the highlands of Massachusetts were allocated in this manner by 1760 and settlers from southern New England began moving into central and northern Vermont by way of the Champlain and Connecticut River valleys. The more rugged and remote areas of the northeastern highlands and Green Mountains were not settled until the 1820s.

**Agricultural Development of Upland New England**

In the approximately two to three centuries that have elapsed since European settlement, the interior and non-urban regions (primarily upland, hill country) of New England underwent a series of dramatic changes in population density and distribution, social organization and economic base that have exerted long-lasting impacts on the natural environment. Although time-transgressive across the region, often occurring earlier in the south and near the coast, many of these changes were part of regional and generalizable transformations (Figures 8 and 9; Cronon, 1983). Some of the changes occurred rapidly and were true revolutions, in terms of their alteration of lifestyles and their ecological consequences (Merchant, 1989).

Most towns were carved de novo from Indian lands with an initial objective of establishing adequate numbers of settlers and agricultural areas for self-sufficiency. In the seventeenth century, towns were initially based on the European model of a centralized and common field system (Donahue, 1983; Garrison, 1985). However, this
Figure 7. Expansion of the New England frontier from the late 17th century to 1812. Note the initial concentration along the coast and Connecticut River valley during the period of the Indian wars in the 1670s, followed by rapid expansion. From Robinson (1988).

Figure 8. Historical changes in the extent of forest cover in the New England states. Despite environmental, geological, biotic, and social variation across the region, the timing and extent of deforestation and reforestation are remarkably similar. Data were compiled by E. M. Gould, Jr., from the U.S. Census. Baldwin (1942) and unpublished sources.
organizational pattern was abandoned in the early eighteenth century in favor of a uniquely New England model of dispersed settlement and individual ownership of private land. Towns (the entire area of a township) were approximately 6 x 6 miles, which represented a practical size in an era of foot transportation, such that all inhabitants were easily within one hour of the village center, the meetinghouse, and church (Gould, 1978). With the General Court providing land, the first years in a town's history were usually marked by land speculation and trading, with few of the original proprietors actually settling on their land (Willson, 1855; Gates, 1978).

In the hilly uplands, hilltops were often selected for the village center and initial clearing as they supported the best agricultural soils characterized by good drainage and relatively few stones (Botts, 1934; Bogart, 1948; Black and Wescott, 1959). In contrast, settlers in broad valley areas took advantage of the level and easily tilled plains for much of their agricultural activity. Land was cleared through girdling and cutting of trees, followed by the burning of slash and wood and the planting of successive grain crops and then corn (Preston, 1822). Land use was determined by a careful reading of the land based on topography, moisture and forest vegetation and frequently assisted by extensive trial and error (Belknap, 1792). In highland areas of New England, individuals were documented as initially clearing 0.5-2.0 ha of forest per year for agriculture (Raup and Carlson, 1941; Bogart, 1948).

Through much of the eighteenth century dispersed, low-intensity agriculture and home- and village-based artisanry were the dominant employment, family occupation and economic base of rural New England (Gates, 1978; Garrison, 1985). Populations were dispersed and low (e.g. 20-35 per km²). Farmers developed their holdings of 10-40 ha into a mixture of woodland (10-25%), woodland-pasture (10-25%), open pasture (50%) and a limited extent of arable land (<10%) for grain and diverse crops (Figure 9; Garrison, 1987; Raup and Carlson, 1941). Few individuals maintained the livestock, land base or equipment necessary for all of their own needs; however, in the aggregate and through cooperation and exchange, townships were largely self-sufficient (Pratt, 1981). All towns supported diverse artisans, shops, mills (for grain, wood and linen) and tanneries (Pewson, 1895). Roadnets were developed primarily for internal circulation and provided relatively poor access to distant markets (Raup and Carlson, 1941). Despite these drawbacks, the amount of trade and travel noted in farm journals of the day was remarkable (Stabler, 1986). Beef (self-transportable; Gates, 1978) and potash provided the major exports from hill towns (Bogart, 1948; Multhauf, 1981), timber was a more important commodity along watercourses, and diverse agricultural
19th-century Britain (1871). The growth of the railway network provided new opportunities for the movement of goods, people, and ideas. The factory system enabled the production of goods on a large scale, and the emergence of new technologies, such as the steam engine, revolutionized industry. The period also saw the rise of a middle class, which began to demand higher standards of living, leading to changes in the housing and food systems.

The Industrial Revolution transformed England into a major power in the global economy. The expansion of trade, particularly with the Americas, India, and China, led to a dramatic increase in wealth and power. However, this was not without its challenges. The rapid growth of the economy led to social unrest and a widening gap between the rich and poor.

The 19th century saw significant social and political changes. The Reform Act of 1832, which expanded the voting rights for men, was a key moment in the struggle for social justice. The period also saw the rise of labor movements and the demand for better working conditions.

In conclusion, the 19th century was a time of great change and transformation. The growth of industry, the expansion of trade, and the rise of new technologies all played a role in shaping the modern world. The challenges of this period laid the foundation for future developments. The 20th century would see even more significant changes, but the groundwork had been laid during the 19th century.
transportation to markets: urban towns and their adjacent areas concentrated on
cordwood, market crops and milk, more distant towns shipped butter, cheese and hay
(Pabst, 1941; Baker and Patterson, 1986).

Growing industrial activity in valley towns and large mill towns (e.g. Worcester and
Lowell, Massachusetts, the Naugatuck Valley, Connecticut and Providence, Rhode
Island), coupled with a good distribution system eliminated much of the need for local
production and artisanship. The result was the closure of many village shops and small
factories and a decline in the home-production system, beginning as early as 1850 in
central Massachusetts and 1870 in northern Vermont (Raup and Carlson, 1941; Bogart,
1948; Thorbahn and Mrozowski, 1979). A major demographic shift began as especially
the young left farm villages for the cities and the midwestern states (Pabst, 1941; Gates,
1978; Barron 1984). In Vermont, between 1840 and 1900, 42% of the towns
experienced greater than a 25% decline in population (Robinson, 1988). In this period
40% of the natives emigrated from the state and the urban population increased over 80%
(Barron, 1984). Throughout New England this period of agricultural and industrial
specialization was accompanied by a concentration of population, energy, and human
activity (Figure 10). Parallel the demographic shift, there occurred widespread
abandonment of farmland: between 1850 and 1900 approximately nine million acres of
new forest established naturally on former farmland in New England (Barraclough and
Gould, 1955). In Vermont, New Hampshire and Maine two million acres of cleared land
were reforested from 1880-1900 and more than 11,000 farms were abandoned
(Robinson, 1988).

There were many causes for the decline in rural agriculture, small industry and
population; however, changes in the fertility of the land was not prominent among them
(Black and Wescott, 1959; Raup, 1966; but see Donahue, 1983). New England farms
were productive, farmers were prosperous (Raup and Carlson, 1941), and even at the
peak of agricultural abandonment productivity of New England farmland compared
favorably with other parts of the country (U. S. Census, 1880; Bell, 1989). In fact,
there is evidence that the quality of tilled land improved through the eighteenth and
nineteenth centuries in hill towns (Jones, 1991).

There were disadvantages to New England land; for example, the soil is stony and
small field sizes were not conducive to the scaled-up agricultural practices accompanying
increased mechanization. However, the major factors operating in the agricultural decline
appear to have been largely external to the land. These primarily social factors included a
growing attraction to the life, jobs and financial benefits of cities and industrial activity, a
declining interest in agricultural lifestyle, a decrease in economic opportunities in small

Throughout the 19th century and earlier, the majority of the state's population lived in rural areas, primarily engaged in agriculture. As the 20th century progressed, the effects of industrialization and urbanization began to impact the region. The graph illustrates the trend of lumber production in New England from 1869 to 1946, showing a decrease in production as the agricultural economy shifted and new industries developed.

**New England 1869-1946**

**Trend of Lumber Production**

The decline in lumber production is evident, reflecting broader economic changes in the region. The transition from a predominantly rural economy to a more industrialized one is a key theme throughout this period.

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**Rural Transformations During the Last Century**

As the population of rural towns declined, there was a parallel reduction in the local farming community. The transition to more urbanized and industrialized areas is a significant aspect of New England's history during this period.

**David Foster**
Many of the mill and valley towns and even leading cities of the industrial revolution have been drastically changed by international competition and resulting high levels of unemployment. The forest landscape, however, continues to receive less intensive use. The scattered farming that does occur is largely monoculture (e.g., dairy cows), limited in geographical scope, and yet generally more productive than ever (Rozman and Sherburne, 1959). Concentration on the best lands, high quality imported feed, and better breeding have resulted in decreased numbers of farms, farmland and even cows with little reduction in production (Meeks, 1986). Although the modern demand for lumber is the greatest in history, production is near the lowest in the past century (Dunwoody, 1974). Meanwhile, New England’s wood products are being provided substantially from outside sources while the local timber base continues to increase (Gould, 1966).

Forest and Ecosystem Response to Land-use History

An assessment of historical changes in the forest conditions of New England faces numerous challenges: (1) the precolonial ecosystems were dynamic and thus there are no baseline or pristine conditions with which to compare; it is a continual problem to separate out effects of human activity from those of natural disturbance, climate change, and forest growth (Spurr, 1950; Raup, 1979; Hunter et al., 1988; Sprugel, 1991); (2) no good examples of unaltered forests exist for comparison due to the long and pervasive impact of altered disturbance regimes, introduced pathogens, modified animal populations, and changed atmospheric conditions; and (3) there is an absence of consistent historical documentation.

Nevertheless, it is clear that European settlers introduced novel disturbances of a magnitude, frequency and intensity unlike processes operating in the presettlement landscape. Thus it is valuable to evaluate the available evidence concerning the role and nature of changes in forest communities over the past 200-300 years and to compare them to evidence from the time of settlement or the paleoecological literature.

Changing extent of forest land

Considerable regional variation exists in the timing and extent of changes in the forest area across New England. For example, large portions of the Connecticut River Valley were settled and cleared by the late seventeenth century and remain open today whereas the adjoining uplands, settled later, have gone through a complete cycle of deforestation and reforestation (Garrison, 1987). In contrast, suburban areas around Boston, Providence and Hartford are undergoing a secondary deforestation and fragmentation as second-growth forests are being cleared for housing developments and commercial activity (MacConnell, 1975).

Despite this variability the regional pattern of deforestation and reforestation is remarkably consistent (Figure 8). With the exception of Maine, where large northern tracts have never been cleared, each of the New England states shows a major decrease in forest area through the late 1700s, a peak of open, agricultural land from 1830-1890 when only 20-40% of the uplands remained forested, and rapid reforestation through the late nineteenth and early twentieth centuries. The northern states (Vermont and New Hampshire) lag somewhat behind those to the south in terms of the timing of these trends. At present, the New England states range from 65-85% forested. Within this regional setting the upland hill towns, like Petersham, Massachusetts, present an extreme. Settled late relatively to much of eastern Massachusetts, Petersham was cleared rapidly for agriculture (Figure 9). The maximum extent of cleared land (approximately 85%) greatly exceeded that of the state on the whole and the process of reforestation on abandoned land proceeded much more rapidly. Today Petersham is 95% forested, compared to the state average of 70%.

Changes in the pattern of forest land

Very little is known about the detailed pattern of deforestation and reforestation within any region of New England and thus we have a very incomplete understanding of what the landscape distribution of forests was at different periods of time. Historical information and a consideration of agricultural activity indicates that local clearing occurred outward from established homesteads and roads towards the back of individual properties (Averill et al., 1923; Foster, 1992). In many hill towns this would have resulted in the initial opening of land along major hill tops and ridges and progressive clearing of forest into valleys, rocky slopes and more inaccessible locations (Bogart, 1948).

At the height of agriculture the forest remnants comprised a highly fragmented system of discontinuous woodlands (Figures 12 and 13; Hawes, 1933). Historical studies suggest that most farmers maintained small woodlots as a source of fuelwood, poles and small materials, often on rocky or wet sites (Averill et al., 1923; Cline et al., 1938). Larger forest areas were scattered throughout the countryside on relatively remote locations or on shallow and poorly drained soils (Fisher, 1921). Preliminary analysis.
Figure 12: Forest cover changes in north-central Massachusetts in 1830 and 1980.

**Shrubland changes in the forest**

Since the 1960s, land use in New England has been influenced by a combination of factors, including economic changes, increased population density, and changes in land management practices. The transition from a forested landscape to one dominated by shrubland has been a significant change in the region.

**Coastal and marine areas**

The impact of coastal and marine environments on land use in New England is complex. Coastal areas are subject to a variety of human activities, including fishing, tourism, and recreation, which can have significant ecological impacts. The maintenance of healthy coastal ecosystems is essential for sustaining these activities and protecting biodiversity.

**Historical perspectives**

Understanding the historical context of land use in New England is crucial for managing current and future land use decisions. The region's past is marked by a rich tapestry of cultural and ecological interactions, which continue to shape its present and future.

**Current trends and challenges**

As New England continues to evolve, land use trends and challenges will persist. The need for sustainable land management practices, coupled with the increasing demand for natural resources, will require innovative solutions to ensure the region's environmental and economic viability.
Figure 13. Maps of four townships characteristic of different physiographic regions in central Massachusetts depicting distinctive amounts and patterns of forest, open land and meadow in 1830 and 1980. See Figure 12 for the location of the townships.

Figure 14. The town of Petersham, Massachusetts depicting (a) the distribution of stone walls, (b) broad soil characteristics and (c-f) the pattern of reforestation from the approximate height of agricultural activity in 1830 to the modern period. In the map of 1900 stippled areas depict areas of old field white pine established on fields abandoned in the previous 30 years.
not address the question of whether human activity has altered substantially the
recreation of the physical environment or increased the New England landscape does

Changes in Speeies Composition

Land continuously cleared and then drained by the time of the colony.
and extensively cleared and then drained by the time of the colony. The

Lowering the high-level sea surface in the New England coastal region of the
1600s was an important factor in land use changes, particularly in the

18th and 19th centuries. The expansion of

The development of a successful

The even-aged and mosaic quality of the forests remains well to New England's

The even-aged and mosaic quality of the forests remains well to New England's

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DAVID FOSTER
composition of forest communities and the relative abundance of species in this region. The answer appears to depend on the scale of analysis (Siccama, 1971; Foster, 1992). Studies based on early forest descriptions, land surveys, and pollen records suggest that on a regional basis the broad distribution of species and forest types has altered little across New England (Raup, 1957). In central Massachusetts, for example, an analysis of vegetation descriptions on a township basis reveals an elevational and latitudinal zonation of central hardwoods, transition hardwood and northern hardwood forest that broadly parallels the modern map (Westveld, 1956; Foster, 1992).

On a stand and landscape scale, however, studies of old-growth forest, fine-scale pollen analysis, and forest reconstruction indicate that considerable change has occurred in the relative abundance and distribution of species and in the relative importance of particular forest types (Figure 15; Winer, 1955; Siccama, 1971; Whitney and Davis, 1986; Glotztein et al., 1990; Foster and Zebryk, 1993). In fact, the inability of many early studies to explain forest composition on the basis of site properties alone has led to a widespread conclusion that land-use history closely regulates local vegetation type (Merrill and Hawley, 1924; Stout, 1952; Goodlett, 1960).

An increase in pioneer or early forest species has been widely cited as the major cumulative impact of historical land-use activity (Lutz, 1928; Spurr and Cline, 1942; Smith, 1979). Including such trees as gray birch, aspen, pin cherry, black cherry and red cedar, these pioneers increased as a result of the widespread disturbance and the early successional habitats created by cutting, clearing, and burning. Repeated cutting, grazing and fire also selected for hardwood species that sprouted prolifically, including chestnut, oak, red maple, birch and hickory (Graves and Fisher, 1903; Frothingham, 1912; Fisher, 1931). Consequently, sprouters increased, especially in forests utilized for fuelwood and charcoal around cities and in mining areas (Winer, 1955; Whitney, 1993).

Chestnut is the preeminent example of a sprout-hardwood species that benefited greatly from repeated human disturbance to forests (Paillet, 1982; Russell, 1987). Producing extensive basal dormant buds and capable of phenomenal rates of height extension and diameter increment when reproducing vegetatively (Zon, 1904; Paillet and Rutter, 1989), chestnut responded to cutting or fire by massive proliferation and rapid stand dominance (Murdock, 1912; Foster et al., 1992). Palaeoecological studies indicate that the abundance of chestnut increased substantially from pre-settlement time through the early twentieth century when the chestnut blight was introduced on trees imported from Asia. By the turn of the twentieth century chestnut accounted for approximately 50% of the standing timber in Connecticut (Frothingham, 1912).

White pine is another species that has undergone major changes in abundance and

Figure 15. Pollen diagram from the humus soil in a hemlock forest at the Harvard Forest, Petersham, Massachusetts. The site is a primary forest that was never clear-cut early in the settlement period (at about 18 cm depth) and then cut repeatedly for firewood and other fuel; the site was cleared of most forest cover by the mid-nineteenth century when the Thanksgiving Day Fire burned much of the forestland. Sugar maple (Acer saccharum) and sugar pine (Pinus rigida) have gradually increased to the present. From Foster et al. (1992).
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Occasional studies have identified species thought to be restricted to or more abundant in primary woods (e.g. Niering and Egler, 1966). In Connecticut, Nichols (1913) suggested that *Hamamelis virginiana*, *Kalmia latifolia*, *Cornus alternifolia*, *Acer pennsylvanicum*, *Viburnum alnifolium* and *Taxus canadensis* occur predominantly in forest areas never cleared. This list was largely corroborated by Whitney and Foster (1988) in a study focused on northern Massachusetts and southern New Hampshire. Following on more extensive research in Great Britain (see Peterken, 1977; Peterken and Game, 1981, 1984) it has been argued that the major factors restricting colonization of this group of species into secondary forest included (1) low seed production and dispersal, (2) possible changes in soils through agricultural use, and (3) competition by established plants (Whitney and Foster, 1988; Gerhardt, 1993). Peterken’s studies in England indicate that as much as one-third of the flora has not effectively colonized secondary forests from primary forest refuges (Peterken and Game, 1984). However, this work also suggests that survival for plant species in the primary forests is largely unaffected by forest area or degree of isolation (Peterken and Game, 1981). Rather, the major loss in species diversity has come about because the remaining primary forests cover only a subset of the original forest sites and woodland species.

One study that has attempted to examine floristic relationships with historical and environmental factors was reported by Foster (1992) from central Massachusetts. Using Canonical Correspondence Analysis it was shown that a combination of edaphic factors (soil moisture and slope position) and land-use history (primary/secondary woodland, cutting history, abandonment date and the distinction between pasture and cultivated lands) provided a significant and informative model of stand and species variation. In this study of the Harvard Forest, primary forests were concentrated on intermediate to poorly drained sites and were characterized by many of the species listed by Nichols (1913) and Whitney and Foster (1988).

Altered seed pools are one critical legacy of land-use activity that will continue to influence the future dynamics of the vegetation. The extreme longevity of seeds of the weedy species that are characteristic of old field and early successional habitats results in a long-term imprint of past vegetation. The seed pools in second-growth forests are often compositionally distinct from the existing vegetation and are dominated by field and shrubland taxa, such as Gramineae, Polygonaceae, *Comptonia*, etc. (Livingston and Allessio, 1968; del Tredici, 1977; Ellison, 1992) that were growing on the site 50-100 years earlier. When such second-growth forest extensively disturbed, the resulting vegetation response is often unexpectedly dominated by agricultural weeds, rather than forest species. For example when the more than 200-year-old Cathedral Pines forest, a
The forest landscape is a complex system of interacting ecosystems, where different populations of plants and animals coexist and interact in a dynamic equilibrium. Major factors that influence the forest landscape include climate, soil conditions, human activities, and natural disturbances such as fire and disease. Understanding these interactions is crucial for effective forest management and conservation.

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different sites and soils, the differential susceptibility of different physiographic units and soils to these effects, and the subsequent history of vegetation on the various sites.

In addition to direct effects on soils there is the potential for indirect removal of nutrients from sites through the harvesting of timber and agricultural products. For example, the extensive production of potash from New England clearly represented a literal export of nutrient capital from the uplands. Some authors have argued that many of these nutrients were extensively redistributed across the landscape. For example, nutrients from pastures may have been removed as forage by grazing animals and added to tilled fields in the form of manure supplements (Jones, 1991). On a broader scale hay produced on the uplands of Massachusetts in the summer was consumed by cattle in the Connecticut River lowland in the winter and then added to lowland fields as fertilizer (Garrison, 1987). The resulting movement of nutrients may have accentuated differences in fertility that already occurred naturally in the landscape.

Attempts to address these nutrient movement questions using historical sources provide equivocal results. A study by Jones (1991) of agriculture in Deerfield and Petersham, Massachusetts, indicated that crop yields on tilled fields increased continually in both towns from 1780 to 1850. Although it was argued that the source of the apparent nutrient inputs (i.e. manure) to the crop fields came at the expense of inputs to hay fields, hay production held fairly constant through the same period. Recent studies by J. Aber and J. Melillo at the Harvard Forest provide indirect evidence for nutrient re-allocations within the colonial landscape (Aber et al., 1991). In experiments designed to test the response of forest communities to nitrogen inputs these researchers discovered that, contrary to their expectations, conifer stands were more nutrient-rich than nearby hardwood stands. This finding runs counter to the general observation that conifer species dominate on less fertile and more acidic sites but can be explained on the basis of land-use history. In central New England many old-field white pine and conifer plantations occur on the most recently abandoned sites such as former tilled fields, whereas many hardwood forests are second-growth stands on old pastures. The tilled sites, probably initially more fertile, received manure supplements for years. Thus, the soil characteristics of the conifer stands reflect history rather than an equilibrium setting.

Terrestrial and aquatic linkages

Lake sediments provide a continuous record not only of the changes that occur in the terrestrial vegetation but also dynamics of the lake system itself. Because the nature of the recording medium does not change through time lake sediments provide a consistent record of changes in water quality, organic and inorganic inputs, biota and productivity.

Most lake ecosystems in the northeastern United States exhibit profound changes during the historical period despite a lengthy Holocene record of relatively little change. Sedimentation rates increase, often markedly, and the inorganic fraction of the sediment increases, reflecting soil instability and erosion across the watershed. Associated with mineral inputs is generally an increase in nutrient loading, which often triggers increased primary productivity (Brugam, 1978a). In severe cases, the enhanced productivity can lead to increased decomposition in the lake water, which can consume available oxygen resulting in anoxic conditions and fish mortality.

Detailed studies of these changes indicate that lake and upland ecosystems are tightly coupled and that lakes respond rapidly to alterations in land use. As lake sediments integrate the activity in the larger watershed the history of changes may be complex. Two studies that show the detail of these changes and their linkage to land-use activities include research by Brugam (1978a/b) in Connecticut and Engstrom et al. (1985) in Vermont (Figure 17). Brugam's study of Linsley Pond in southern Connecticut illustrates a sequence of progressively more intensive changes in the upland ecosystem. Following deforestation a subtle increase in primary production accompanies changes in pollen frequencies. Farming in the watershed in the early 1800s led to increased organic erosion, input of nutrients from manure and household refuse and a noticeable change in the algal composition. A fundamental alteration of organic and inorganic matter fluxes to the lake and enhanced nutrient inputs parallel expansion of dairy farming in the watershed in the early 1900s. Suburban development in the 1960s resulted in hypereutrophic conditions.

Engstrom's study on Harvey's Lake, Vermont evaluated the feasibility of restoration efforts of the eutrophic lake based on the extent to which modern conditions might reflect a departure from the presettlement situation (Figure 17). Examining the inorganic geochemistry, pigments and diatoms as well as pollen, the researchers showed two major increases in primary productivity (1780 and 1945) associated with extensive logging activity and a major increase in the input of dairy wastes into the lake. Construction of a sawmill on the primary inlet in 1820 coincided with the onset of anoxia and the incorporation of woodchips into the sediments. Anoxic conditions, presumably resulting from the decomposition of sawmill debris, lasted until 1920 when the mill was closed. Dairy waste enrichment of the inflowing stream, accompanied by an expansion of summer homes, produced a dramatic shift in the algal populations to blue-green algae and a new development of anoxic conditions. Thus, modern limnological conditions are markedly different from those that prevailed for over a thousand years before settlement
Future Changes in New England's Forests

Species that benefit from the clearing of woodland...
Table 1. Current status and tally of wildlife and plant species in Massachusetts showing native, introduced extinct and extirpated species listed in the state since 1620. Adapted from Bickford and Dymon (1990).

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>Native</th>
<th>Introduced</th>
<th>Rare</th>
<th>%</th>
<th>SC</th>
<th>Fed Listed</th>
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<tbody>
<tr>
<td>Mammals</td>
<td>94</td>
<td>58</td>
<td>22</td>
<td>8</td>
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<td>7</td>
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<tr>
<td>Birds</td>
<td>434</td>
<td>188</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Reptiles</td>
<td>30</td>
<td>24</td>
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<tr>
<td>Amphibians</td>
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<td>15</td>
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<tr>
<td>Fish</td>
<td>72</td>
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<td>Total</td>
<td>659</td>
<td>618</td>
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<td>28+</td>
<td>6</td>
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<td>14</td>
<td>2</td>
<td>14</td>
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</tbody>
</table>

* End: Endangered, Th: Threatened, SC: Special Concern
Table 2. Timber growth versus removal in the New England states from 1935 to 1985. Growth exceeded removal in all but the earliest period as indicated by the percent (G-R) increase. Data were obtained from Baldini (1942, 1944), Irland (1982) and USDA (1990).

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth</th>
<th>Removal</th>
<th>G-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>1304</td>
<td>638</td>
<td>201%</td>
</tr>
<tr>
<td>1944</td>
<td>440</td>
<td>386</td>
<td>124%</td>
</tr>
<tr>
<td>1952</td>
<td>1057</td>
<td>555</td>
<td>167%</td>
</tr>
</tbody>
</table>

Values given in millions of cubic feet of wood.
Figure 19. The progression of suburbanization in the state of Massachusetts during the last half of the 20th century. A growing population and 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 Wilde and Tainter (1971).

Figure 20. The annual net flux of carbon to the atmosphere ($P_{gC} = 10^{15}$ grams) from North America and Latin America resulting from human land-use. The graphs illustrate that whereas deforestation and increased agricultural activity across Central and South America have led to accelerated release of CO$_2$ during the last 50 years, the same period has witnessed decreased emissions in North America. A major contributor to this continent-wide decline is the conversion of former agricultural land back to forest and consequent storage of carbon in forest ecosystems. From Dale et al. (1991).


BROWN, F. (1895) Decline and Fall of Peterham, Worcester County. Town of Peterham, Massachusetts.


COOK, H. O. (1917) The forests of Worcester County. The results of a forest survey of the fifty-nine towns in the county and a study of their lumber industry. State Printing Office, Boston, Massachusetts.


Acknowledgements


