

Reconciling the Effects of Historic Land Use and Disturbance on Conservation of Biodiversity in Managed Forests in the Northeastern United States

Abstract

In the northeastern United States, nearly all lands have been impacted by European settlers and their followers since the 1600s. Settlers modified the landscape through clearing, plowing, grazing, logging, burning, abandoning, developing, and fragmenting what was once nearly contiguous forest. Our study was designed to 1) determine the composition, dynamics, and natural disturbance regimes of presettlement forest communities in the northeast, 2) describe the changes and biodiversity impacts imposed on the landscape by human land use over the past 400 years, and 3) offer realistic suggestions for sustainable forest management that could simulate presettlement ecological processes while supplying timber resources, thus favoring natural species assemblages and promoting long-term conservation of biodiversity in managed forests.

The study area, the “northeastern United States” included Ecoregions 221 and M212 northeast of New York, Pennsylvania, and New Jersey, as well as Ecoregion 212. Three forest types were defined within this area based on a review of literature: 1) pine barrens, 2) transition hardwoods, and 3) northern hardwoods. A fourth type, central hardwoods, and a fifth type that occurs at high latitudes and elevations, spruce-fir, were not included in the study. An extensive literature review revealed that each forest type had a unique presettlement species composition and structure that responded to a suite of natural disturbances and their effects. In contrast, historic land uses such as agricultural abandonment and extensive cutting have homogenized forest composition and structure across the northeastern landscape. Therefore, we used specific data on the frequency and intensity of natural disturbance and the likely composition and age structure of natural vegetation to inform management guidelines for each forest zone. These guidelines were constrained by the legacy of former land use on the current landscape, as well as effects of current ownership patterns, fragmentation, and the economic feasibility of mimicking natural forest composition and dynamics with silviculture.

Deliverables for Project B1.1 include:

- A final report (this document), consisting of three major sections, each detailing presettlement, postsettlement, and suggested management for each of the three forest types.
- Two outreach publications will be prepared in conjunction with the University of New Hampshire Cooperative Extension. These will be oriented for private landowners and practicing foresters.
- Poster presentations at regional conferences, including The Wildlife Society and the New England Society of American Foresters.

- A website to make our findings available to landowners, managers, and the general public. It supports all of the information from the final report in a user-friendly and logical layout that includes a clickable map of the Northeast, plus downloadable resources such as our conference posters, extension publications, a full bibliography, and links to various organizations.

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Introduction

Much of the work on landscape ecology and forest management to date has focused on a simplified model, representing the landscape as a dichotomous patchwork of “pristine” forests and managed areas. In such an approach, the “pristine” is viewed as normative, and a major goal of (or constraint to) forest management is the maintenance and restoration of pristine elements within the landscape matrix. Whether or not such an approach has merit, for example, in western National Forests, it may be of questionable value in eastern landscapes that already bear the imprint of centuries of settlement and culture. A more subtle view, recognizing the influence of history on forest management objectives, opportunities, and constraints, is needed.

Unlike in other portions of the United States, forests in the Northeast have substantially increased in extent during the last century. Historically, the majority of this region was cleared to accommodate colonial agriculture and the timber needs of a rapidly expanding population. Subsequent abandonment of many of these lands in the mid 1800s has resulted in extensive stands of second-growth forest, and the region now includes the most extensively forested states in the nation. For example, forests cover more than 80% of the land area of Maine and New Hampshire. However, recent inventory data suggest this trend is reversing, especially in southern and central New England, as suburban sprawl competes with traditional land uses.

Because the majority of plants and animals native to the Northeast are affiliated with forests, one might conclude that the abundant forests in this region provide adequate habitat for most taxa. However, the majority of the mid-successional stands that dominate the region lack important habitat features (e.g., large diameter trees, canopy gaps, and coarse woody debris). Additionally, species that require regenerating or mature stands may be experiencing habitat shortages. Left idle, it may take a century or more for the forests in this region to mature and develop the structural complexity and diverse age distributions they currently lack. Management of these forests is further complicated by a range of landscape modifications and ownership patterns that cannot easily be reconciled. Extensive suburban/urban developments with associated road networks have substantially fragmented the landscape and continuity. These modifications have altered community interactions, such as predation and competition, provided avenues for the invasion of aggressive alien species, and affected demographic processes (especially dispersal) among a variety of organisms.

It is clear that historic land-uses are having a wide range of influences on contemporary forest communities. A comprehensive understanding of these impacts is an essential first step in assuring that current levels of biological diversity will be maintained. This information should then be placed in the context of current land uses to develop realistic approaches for using silviculture to provide a range of habitats within forest ecosystems.

Purpose

The driving purpose of our report is to provide realistic silvicultural considerations and recommendations for foresters and landowners on how to effectively and sustainably manage northeastern forests for timber while also protecting native biodiversity. As cultural land use practices have degraded northeastern forests over the last 400 years, threatening biodiversity, the silvicultural methods we propose are designed to help rehabilitate present-day forests by reintroducing elements that were important to presettlement forest dynamics. To accomplish this goal, the following three objectives must be met:

Objective 1:

Describe as accurately as possible the species composition, structure, and dynamics of presettlement northeastern forests. Included in this synthesis is a comprehensive understanding of the types of natural disturbances that occurred in these forests and how they affected and controlled presettlement forest dynamics, including native biodiversity.

Objective 2:

Describe the major land uses that impacted northeastern forests in the last four centuries since European colonization. We develop an understanding of their historical effects on forest composition and biodiversity, and how the legacies of these land uses continue to influence forest dynamics and biodiversity today. We assess how current species composition, ecological processes, and disturbance regimes are different from their presettlement counterparts.

Objective 3:

Review the current knowledge about silvicultural and management options, including methodology and outcomes, focusing on how specific techniques impact forest regeneration and biodiversity. We propose that management techniques that follow natural models for forest disturbance may best sustain the diversity of plants and animals native to the northeast by reestablishing ecological processes that have been lost or modified since presettlement. Our recommendations should balance these goals while also being economically sound, providing sustainable yield, and recognizing current and historical cultural land use factors that affect their practicality.

Finally, we want to make our recommendations widely available to forest managers. We propose to do this through our final report to NCSSF, presentation of our findings on our project website, publication of our findings through the University of New Hampshire Cooperative Extension, as well as to make our project known through two presentations at regional conferences.

Summary of Results

Our report is divided into three major sections, each addressing one of the major forest types in the northeastern United States, as determined by a review of the current literature. These include 1) pine barrens, 2) transition hardwoods, and 3) northern hardwoods (Figure 1; spruce-fir and central hardwoods are not included in our study.)

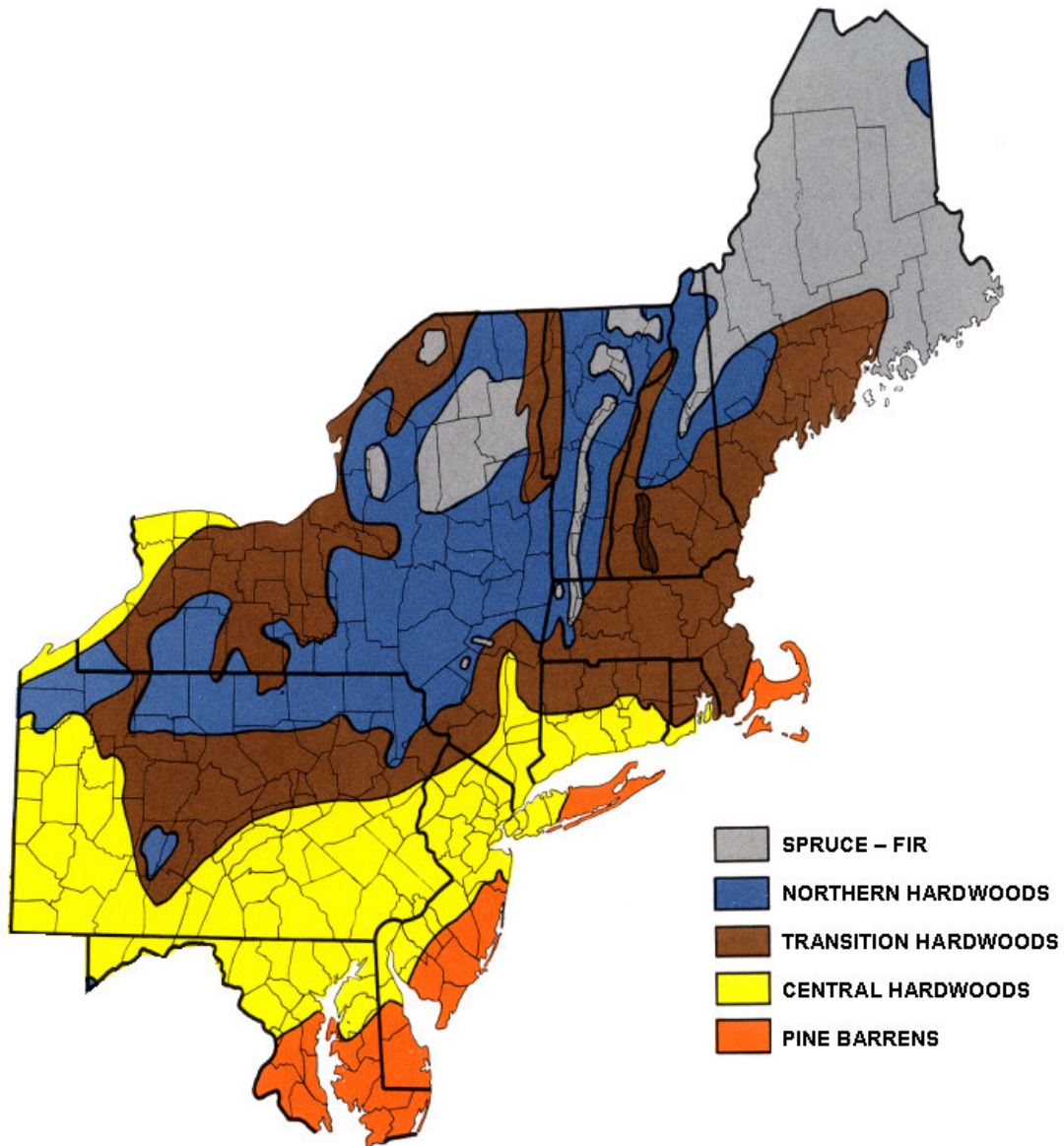


Figure 1. Map of the northeastern United States showing five forest types. After Lull (1968); forest type names are ours. Dark brown area in southwestern New Hampshire represents a blending of Transition Hardwoods and Northern Hardwoods at higher elevations.

Each major section of our report includes the following subsections:

- 1) Presettlement Vegetation and Natural Disturbance – a description of what is known about pre-European forest composition, dynamics, and disturbance regimes.
- 2) Postsettlement Vegetation and Historic Land Use – a description of the changes in vegetation resulting from 400 years of intensive land use, including the consequences for biodiversity created by human settlement in each forest type.
- 3) Management Challenges and Recommendations – in response to the issues raised above, a description of how forest management may (or may not) be used to rehabilitate existing forests based on reintroducing presettlement elements.

Summary of Results:

Part 1: Pine Barrens

- 1) Presettlement Vegetation and Natural Disturbance

Pine barrens were historically characterized by pitch pine (*Pinus rigida*) and scrub oak (*Quercus ilicifolia*) with an ericaceous understory. Community structure ranged from closed to open woodland or scrub oak, heath, or dwarf pine barrens depending on the return interval of fire. Droughty sandy soils, flat terrain, and flammable vegetation led to a mean fire return interval of 40 years or less. Pine barrens provided habitat for a multitude of specialized species of plants and animals not found in other forest types.

- 2) Postsettlement Vegetation and Historic Land Use

Pine barrens were originally avoided by colonists in an agricultural economy due to poor soils. Areas that were farmed still lack understory flora that was destroyed by plowing. Pine barrens were later exploited for wood and developed for residential, commercial, or industrial uses. Habitat destruction, fragmentation, and fire suppression are the three most important current threats. Without fire for extended periods, shade-tolerant hardwoods invade and exclude fire-tolerant vegetation, and fuel buildup creates the potential for devastating fires that threaten human life and property.

- 3) Management Challenges and Recommendations

Because pine barrens require periodic fire to regenerate, successful management must use fire or else simulate its effects. Shade-tolerant hardwoods and red maple must be eliminated and mineral soil must be exposed to promote regeneration of pitch pine and fire tolerant species. Recurrent surface fires could be used in some buffered locations, but scarification with a plow might be necessary where fire is inadvisable. Silviculture in

pine barrens would be even-aged, be on a rotation appropriate to the local natural fire return interval, and may also include mixtures of white pine to increase economic profitability.

Part 2: Transition Hardwoods

1) Presettlement Vegetation and Natural Disturbance

Transition hardwoods lie between northern and central hardwoods, thus containing elements of both, including beech (*Fagus grandifolia*), birches (*Betula* spp.), maples (*Acer saccharum*, *A. rubrum*), oaks (*Quercus* spp.), and hickories (*Carya* spp.). An abundance of white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*) characterized the zone. Natural disturbance was characterized by large-scale disturbance every 1-4 centuries by hurricanes (frequency increased near the coast), and the northern limit of fire in the Northeast corresponded to the northern boundary of the transition hardwoods zone. Late successional sites undergoing gap dynamics were uncommon, forming in only a few areas not affected by catastrophic disturbance for extended periods.

2) Postsettlement Vegetation and Historic Land Use

Europeans cleared 60-80% of forests in the northeast by 1880 for agriculture, pastures, timber, and fuel. Beginning in the 1840s much of this land was abandoned and reverted back to forest. Today these forests are even-aged, lack structural elements, and have homogeneous species composition dominated by red maple and mid-successional species. High-grading, fire suppression, deer browsing, and introduced pests and diseases have prevented a return to presettlement forest composition. The current lack of many late- or early-successional habitats impacts plants and animals dependent on these habitats. In many ways the transition hardwood zone may be the most modified of forest zones, and land-use legacies affecting current and future forest dynamics may not easily be overcome.

3) Management Challenges and Recommendations

Management of transition hardwoods should mitigate the successional “pulse” resulting from land abandonment in the mid-1800s. Land ownership patterns in transition hardwoods (small parcel sizes) will complicate efforts to address this pulse on a landscape scale. Reintroduction of fire may not be practical at the scale and intensity required to simulate presettlement conditions. Single-cohort stands would have been common due to the action of frequent hurricanes; therefore shelterwood systems applied at varying intensities and rotations, with the preservation of landscape legacies such as large trees and coarse woody debris, would best simulate this catastrophic disturbance and produce landscape heterogeneity that would be favorable to biodiversity conservation. Given the importance of large disturbances (i.e., hurricanes and fire), uneven-aged management should be used sparingly.

Part 3: Northern Hardwoods

1) Presettlement Vegetation and Natural Disturbance

Northern hardwoods were dominated by shade-tolerant beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*), and mid-tolerant yellow birch (*Betula alleghaniensis*). As catastrophic disturbances such as hurricanes and fires occurred at intervals >380 years, these forests often developed into late successional communities favoring shade-tolerant species. Within these later-successional woods, gaps from the death of one to a few trees (25-2000 m²) created a gap-dynamic succession with a rotation time of 75-150 years. Smaller gaps were recolonized by shade-tolerant advanced regeneration, but windthrow gaps larger than 500 m² sustained small populations of shade-intolerant species. Disturbance frequency declined with increasing gap size.

2) Postsettlement Vegetation and Historic Land Use

Northern hardwood forests experienced similar clearing and abandonment patterns as transition hardwoods, again creating a successional pulse of even-aged forest. Areas that were less accessible were clearcut during the period of railroad logging from 1870-1930, and sparks from steam locomotives often touched off slash fires. Current forests are even-aged, have lower populations of late-successional species, and lack structural elements such as snags and coarse woody debris that would normally promote regeneration of light-seeded species and provide homes for multitudes of insects, birds, and mammals. Gap-dynamic processes will not occur until the breakup of these stands in approximately 100-200 years, barring human intervention. In addition, beech bark disease has significantly depressed the ability of beech to sustain many large individuals.

3) Management Challenges and Recommendations

If presettlement forests and disturbance regimes are to be the benchmarks for designing modern silviculture in northern hardwoods, then 30% of the landscape should be early successional, recovering from large-scale disturbance, 40% in uneven-aged forest, undergoing gap dynamics, and 30% in a transitional stage between the two extremes. Such a situation lends itself to the application of both even- and uneven-aged silvicultural methods; however economic and logistical benefits of even-aged silviculture and the problems and risks associated with true uneven-aged silviculture may tend to tip the scales toward even-aged management. Shelterwood systems can be used to manipulate stand composition toward either shade tolerant or intolerant species composition, and a range of shelterwood intensities across the landscape may create habitat for the greatest range of native biodiversity. Whatever silvicultural system is used, it is clear that the development and retention of structural legacies such as large live trees, snags, and coarse woody debris (currently lacking in most stands) will be vital to improving habitat quality for a range of animal species.

Approach

Our project is based on a comprehensive literature review of three major forest types in the northeastern United States: pine barrens, transition hardwoods, and northern hardwoods. Each forest type had distinct tree species composition and stand dynamics, as well as different combinations of human land uses. We utilized refereed scientific journals and published texts to create a knowledge base about presettlement forests, natural disturbance, the changes people have caused since colonization, and the potential of various silvicultural and management techniques to ameliorate negative effects of historic and current land uses on biodiversity.

We synthesized scientific literature relating to the following areas for each forest type:

I. Presettlement Forest Composition and Dynamics

Species composition of presettlement forests was inferred from:

- 1) tree pollen preserved in lake sediments
- 2) historical records of witness trees recorded by surveyors and early accounts of European colonists
- 3) reconstruction of early forests through tree core and forensic analysis
- 4) observations of old-growth stands

Natural disturbance regime of presettlement forests was inferred from:

- 1) charcoal preserved in lake sediments
- 2) eyewitness records and historical documentation of disturbance
- 3) evidence such as fire scars and growth history recorded in tree rings
- 4) life history characteristics of the dominant presettlement species
- 5) dynamics of contemporary stands resembling presettlement forests
- 6) effects of natural disturbances (large and small) on contemporary forests

II. Postsettlement Forest Composition and Anthropogenic Effects

We summarized the effects of human activities in the following categories:

- 1) agricultural development and revegetation following land abandonment
- 2) extensive forest harvesting, including associated slash fires
- 3) fire suppression in the 20th century
- 4) modification of natural animal populations, including extinctions and overpopulation of herbivores
- 5) introduction of exotic species and diseases
- 6) forest fragmentation and parcelization

III. Forest Management Options

We reviewed the outcomes of various silvicultural methods in each forest type, taking into account:

- 1) practical and economic feasibility

- 2) effect on native biodiversity
- 3) effect on subsequent forest regeneration

We assessed the similarity of each silvicultural method to the presettlement disturbance regime, taking into account:

- 1) disturbance frequency
- 2) disturbance size, intensity, and spatial pattern
- 3) structural legacies left by disturbance
- 4) particular species favored or disfavored by disturbance

We then formulated silvicultural recommendations balancing:

- 1) practical and economic feasibility
- 2) similarity to presettlement disturbance regime
- 3) potential to ameliorate problems caused by historic land use
- 4) potential to benefit the greatest degree of native biodiversity

A bibliography of the sources cited in our report is attached to this document.

Deliverables

Status of Deliverables and Projected Completion Dates:

- 1) A final report, consisting of three major sections, each detailing presettlement, postsettlement, and suggested management for each of the four forest types.

Completed.

- 2) Two outreach publications in conjunction with the University of New Hampshire Cooperative Extension. These documents, outlining our findings on old-growth structural legacies and early successional habitats, will be short, well illustrated, and geared to forest managers and landowners. We will also make them available to other states' cooperative extension offices upon completion of the project.

- Will be submitted in Spring 2005.

- 3) Poster presentations at regional conferences, including The Wildlife Society and the New England Society of American Foresters.

Completed.

- 4) A website to make our findings available to landowners, managers, and the general public. It will include all of the information from our final report in a user-friendly and logical layout that includes a clickable map of the Northeast, plus downloadable resources such as our conference posters, extension publications, a full bibliography, and links to various organizations.

Completed. (Extension publications will be added when complete.)

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Appendix 2 – Links to Project Websites

Our project report is available for free download in part or in its entirety at the project website:

<http://www.unh.edu/ncssf/>

The National Commission on Science for Sustainable Forestry (NCSSF), the granting organization that funded this research, has a website at:

<http://www.ncseonline.org/NCSSF/>

The University of New Hampshire Department of Natural Resources, through which this research was conducted, has a website at:

<http://www.unh.edu/natural-resources/>

Appendix 3 – List of Publications

- 1) NCSSF final project report. *Reconciling the Effects of Historic Land Use and Disturbance on Conservation of Biodiversity in Managed Forests in the Northeastern United States*. Available on the web at www.unh.edu/ncssf. This publication is the most detailed version of our findings, which includes descriptions of presettlement forest composition and disturbance, postsettlement modifications of forest composition and dynamics, and suggested management practices to balance sustainable yield with protection of native biodiversity.

- 2) Two publications through the UNH Cooperative Extension that focus on (old growth) legacies and early-successional habitats. These may or may not be forest-type specific. This will be geared to foresters and landowners, will be distributed through UNH cooperative extension, and will include photographs and a summary of management descriptions. This will be submitted for publication as soon as possible after completion of our final report.