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Northeastern Forest Regeneration Handbook

A Guide for Forest Owners, Harvesting Practitioners, and Public Officials

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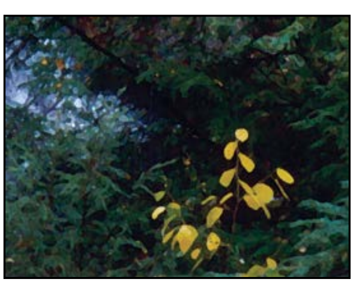


Introduction

This handbook has been prepared to help readers develop an appreciation of how northeastern forests develop and an understanding of forest regeneration concepts, including the importance of disturbance. This information will help landowners and other land use decisionmakers, in concert with professional foresters, make informed decisions about forest regeneration options tailored to their management objectives.

This handbook is divided into five sections.

Section I: Northeastern Forests—Yesterday and Today provides a context for the issues surrounding the natural regeneration of our forests. It begins with a short history of the forest from the glaciers to the period of European colonization and large-scale land clearing through to the present suburban forest. It concludes with the challenges (fragmentation, parcelization, deer, invasive species) that must be met to maintain a healthy and vibrant forest for future generations.

Section II: Environmental Factors explains basic concepts in forest regeneration, including the importance of different combinations of light, moisture, and soil in determining its success or failure. The section then details the adaptations of different species to distinct combinations of light, moisture, and soil conditions, and concludes with an examination of competitive interference among trees striving to form part of the upper canopy.

Section III: Disturbance—The Agent of Change examines the role of disturbance in maintaining habitat and species diversity. The influences that distinct disturbance regimes have on forest composition are also explored.

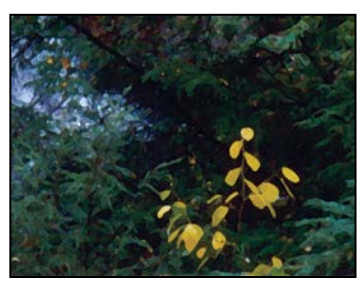
Section IV: Forest Management for Regeneration introduces different methods (prescriptions) of forest management and discusses the influence of each management style on the availability of light, moisture, and growing space for new regeneration. Because the primary reason for harvesting is often either income or a noncommodity amenity such as wildlife, the economic and esthetic considerations of each management method are also presented.

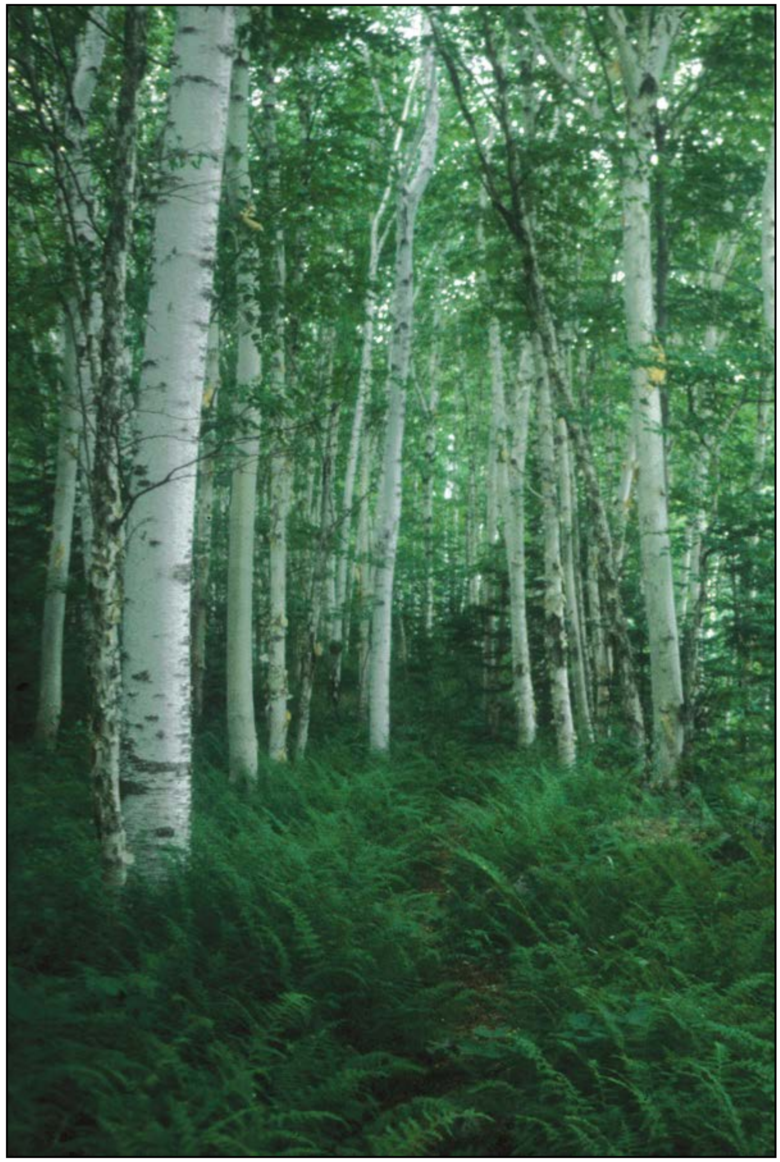
Section V: Species Regeneration Notes details requirements to successfully regenerate specific species. Like the remainder of this publication, this section is not intended to be an authoritative reference, but instead provides readers with sufficient information to make informed decisions about forest management options.

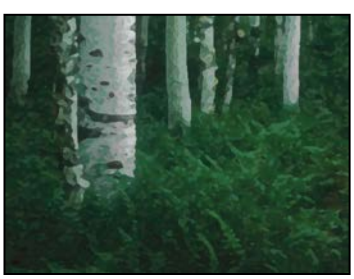
This publication should not replace professional forestry advice when developing a management plan and embarking on regeneration or other forest management activities. The authors strongly encourage landowners to engage the services of a professional forester.

Forests are dynamic—

Seeds disperse, seedlings germinate, grow, and compete with each other and with larger trees. Some trees survive for hundreds of years. The mix of species that predominates the future forest depends not only on climate and soils, but also on management decisions made today. Changes in forest composition will affect the quality and variety of forest resources available to future generations and wildlife.







Section I: Northeastern Forests—Yesterday and Today

Viewed across the landscape, the forests covering our hillsides and valleys seem as though they have always been there. A different story emerges, however, when evidence of human impact on the land from earlier generations is discovered while walking in the woods. Overgrown stone walls outline old pastures and grain fields. Occasionally, the outline of a charcoal mound or a sunken cellar of a farmhouse is evident. The landscape has undergone dramatic changes since European settlement, including large-scale land clearing for agriculture, wildfire, hurricanes, and repeated harvesting. The following pages chronicle the dynamic and resilient nature of the northeastern forest with a special emphasis on disturbances and changes in land use patterns.

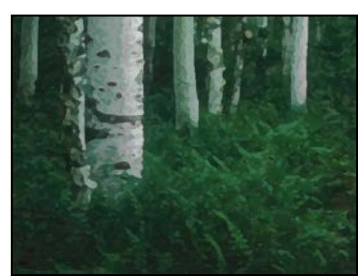
A Short Account of a Long History

Northeastern forests have a history of resiliency and recovery. They are dynamic, always changing. Approximately 20,000 years ago, the landscape was covered by glaciers more than a mile deep. These immense sheets of ice scrubbed the landscape clean. The vegetation that existed before the onset of this last ice age, approximately 70,000 years ago, was obliterated. The native species of the time either became extinct or reestablished themselves in more southerly locations.

Northeastern forests have a history of resiliency and recovery. They are dynamic, always changing.

About 15,000 years ago, global temperatures warmed enough to cause the glaciers to recede to the north, leaving a landscape that was devoid of vegetation and, in some cases, soil. The landscape conditions left behind the retreating ice were similar to arctic tundra, an inhospitable place for plants to grow. Eventually, warming temperatures enabled hardy plant species to begin the process of vegetating the barren, rock-strewn landscape. Thousands of years of climate change produced conditions under which the tundra-like vegetation was replaced in turn by grass prairies, stands of conifers, and, eventually, the predominantly deciduous, broad-leaved forests of today.

During this period of climate change and against this rich backdrop of landscape forces, humans colonized the Northeast. Early Native Americans were a key component of the presettlement forest ecosystem through their influence on forest composition and structure. Indeed, this is one of the few places on Earth where humans have been an integral part of the landscape since the return of life after the glaciers receded. Sizeable portions of the coastal areas and river valleys in the Northeast were kept relatively open by Native Americans for cultivation and summer fishing villages. The forested lands of the region, however, were the primary source of material for shelter, clothing, tools, game animals, fuel, winter dwelling sites, and overland trading routes.



At the time European settlement began in the Northeast in 1620, it is estimated that 90 to 95 percent of the region was covered with forest.

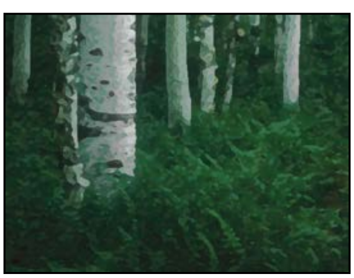
Large upland forest areas were subjected to frequent low-intensity burning by Native Americans to control understory growth. This activity did not usually harm larger trees, but stimulated abundant new growth for deer browse and berry production while improving conditions for overland travel, visibility, and defense. Low groundfires occurring every few years favored species with adaptations such as thick bark, root suckering, and resistance to decay.

Native Americans girdled large trees to provide firewood and used the resulting openings to grow crops. The bark of large trees was stripped for shelter covers, cordage, clothing, and material for large and small vessels. Roots, fruits, and nuts were gathered for food. Sugar maples were slashed in the spring to gather sap, which was then boiled into syrup, a technique they taught to early European settlers. Pine, spruce, and birch sap were also useful commodities. Poles were cut, and tools and weapons were made from wood.

Another resident of the presettlement forest present in great numbers was the lowly beaver. Beavers regularly flooded forested wetland areas and then released the water several years later when their dams were abandoned. These areas revegetated with a lush, diverse growth of young shrubs and trees, to which beavers would return after a few years to repeat the cycle. This cyclical activity, which occurred at many locations across the region, helped to maintain an environment with a diverse collection of early successional plant species and habitat features suitable for numerous birds and fur-bearing animals.

At the time European settlement began in the Northeast in 1620, it is estimated that 90 to 95 percent of the region was covered with forest. The colonists gradually cleared the land to plant their crops and orchards, create hayfields, and build towns. In addition, they harvested the virgin forests for firewood and to provide timber for domestic use and export. Large white pines were used for ship masts. Amazingly, by the mid-1800s, 54 percent of New York, 67 percent of southern New England, and 55 percent of northern New England (excluding Maine) was either in pasture or plowed for food production (Baldwin 1942, Fernow 1894). The percentage of land cleared during this period ranged from nearly entire sections along the coast to only 10 percent in parts of the White Mountains of northern New Hampshire.

The forest, not the local hardware store, provided wood for homes, furniture, wagons, tools, and fuel. Hickory was prized for tool handles, and hickory smoke added a distinctive taste to cured meats. Rot-resistant chestnut poles were used for fences and buildings. Sassafras was used as a teak substitute on ship decks and, because of its reputed power to repel insects, to make beds and chicken coops. An even larger part of the forest was cut for wood to heat houses through the cold New England winters and to cook meals. Undoubtedly many early colonists, borrowing on knowledge gained from the Native Americans, supplemented their diets with foods from the forest, such as American chestnuts, maple syrup, blueberries, and shadbush, which added variety and helped them survive the long New England winters.



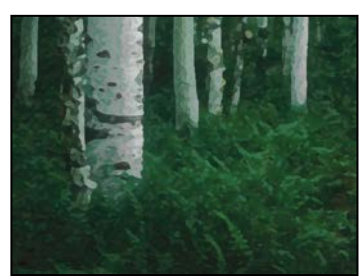
Two events led to the abandonment of many farms in the region. The opening of the Erie Canal allowed farm products from the Midwest to be imported at a lower cost than locally grown food being produced on land with diminishing soil quality. Many farm families moved west to establish new farms on the more fertile soils. The advent of the Industrial Age led other families to move to the mill towns to earn a higher income than could be gained on hardscrabble and overworked farmlands.

Farmlands reverted to forest, the natural vegetative cover for most of the region, but the forests that returned were dramatically different than those that greeted the first Europeans. Uncontrolled grazing and lack of vegetative cover caused the erosion of topsoil and depleted soil productivity. Forests in northern New England that had originally been softwood often grew back as northern hardwood (beech, birch, and maple) or mixed stands. Those that had probably been oak and pine became nearly pure pine. The conversion of farmland to pine, often called "old field reversion," resulted in more pure softwood stands than before. In many cases, the forests that first regenerated on abandoned farmlands have now been harvested many times, and the pure conifer stands that grew immediately after farmland abandonment are converting to more diverse species mixes.

Another period of extensive forest clearing came in the late 1800s to early 1900s in response to the demands of growing industrialization. In Connecticut, for example, entire hillsides were cut to produce charcoal and fuelwood for the local brick, brass, railroad, and iron industries. Stands were typically cut every 20 to 40 years, when trees were still small enough to be handled manually. The advent of logging railroads in the mountainous regions of northern New England and upstate New York, and innovations that allowed softwoods to be used to make paper resulted in the wholesale cutting of forests on the mountains.

Extensive logging depleted timber resources in the region during the late 1800s and early 1900s.

Also in the late 1800s and early 1900s, immense fires, covering thousands of acres or more, regularly roared over the countryside. Between 1900 and 1910, wildfires burned an average of 167,000 acres per year in the region (Plummer 1912). Some of these fires were accidental, caused by escaping sparks from railroads, homes, and industry. However, many were deliberately set to clear the underbrush in the forest to provide better pasture for livestock. This wanton destruction of forest resources spurred the creation in 1885 of a program to protect the Adirondack region in New York—the beginning of forest fire control in the United States. Through the efforts of State and local firefighters, the amount of forest damaged by wildfires in the region each year has been cut dramatically to an average of 5,845 acres in recent years (Fournier 2005).



Impacts to the forest have not been limited to clearing, cutting, and burning. Diseases and insect outbreaks have affected forest structure and composition. Upwards of 25 percent of the forest in southern New England and New York was American chestnut before chestnut blight virtually eliminated this majestic species in the early 1900s. Between 1960 and 1990, gypsy moth outbreaks defoliated forest canopies across large portions of the region. Eastern hemlock is currently threatened by the hemlock woolly adelgid, and the fate of white ash is uncertain given the extent of the emerald ash borer.

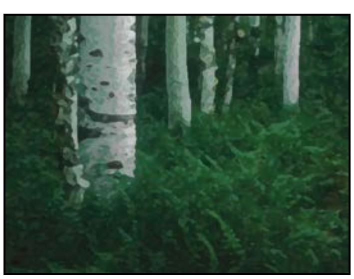
Weather events, including ice storms, microbursts, tornadoes, and hurricanes, have caused widespread forest disturbance. Historical records suggest that severe hurricanes strike the region every 100 to 150 years. The 1938 hurricane severely damaged over 600,000 acres of forest in New England, with an estimated loss of over 2.5 billion board feet of timber. It had a dramatic impact, destroying many of the oldest and largest stands.

Much of the raw materials for the region's prominent forest products industry comes from private forest lands.

The Forest Resource

Today, forests once again dominate the New England and New York landscape—73 percent is forested (Smith and others 2009). Most of the region is fertile and accessible enough to grow and harvest trees for sale or personal use. The majority of productive timberland (54 percent) is in the hands of private individuals, organizations, and families. Corporations own 29 percent; the local, State, and Federal governments are stewards of the remainder (Smith and others 2009). Private forests provide numerous public benefits including high-quality water, open space, wildlife habitat, and recreational opportunities.

First and foremost, forests protect watersheds, aquifers, and groundwater supplies that provide our primary source of clean drinking water. Trees also control air pollution, acting as giant filters to remove dust, particulates, and some airborne chemicals. Trees cool our environment in the summer by recycling water, absorbing some sunlight for photosynthesis, and reflecting some sunlight back into space.



Recent economic figures indicate that forestry, commercial logging, and forest-based manufacturing provided 79,000 jobs and contributed more than $18.4 billion to the region's economy in 2010 (Lopez and Laughton 2012, Mansius 2013). Much of the raw materials for the region's prominent forest products industry comes from private forest lands. Companies manufacture lumber and veneer for products ranging from fine furniture and doors to shipping pallets and wood mulch. Low-grade trees are turned into pulp for paper and chips for energy. Nontimber products such as Christmas trees, wreaths, maple syrup, and ginseng contribute another $80 million (U.S. Department of Agriculture 2004).

Forests contribute to the region's character and its multibillion-dollar tourist industry. People come from all over the country, and all over the world, to view the kaleidoscope of fall colors that year-round residents often take for granted. Healthy forests add to our enjoyment during other times of the year, as well. We mark the end of winter with maple syrup festivals and by noting the first pussywillow flowers. Trees shade our homes and picnics in the summer while white pines amplify the whistling of the wind. Massive oak, maple, white pine, and yellow-poplar tree trunks lend a sense of wilderness to modest urban parks.

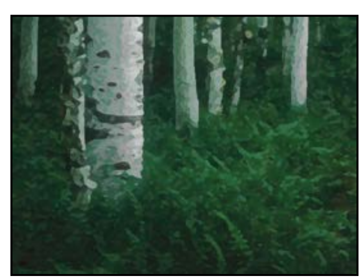
People come from all over the world to view the kaleidoscope of fall colors.

The Changing Forest

The past 400 years has seen many changes in the landscape: from a sea of forested hills to a quilt of agricultural fields and woodlots; from abandoned farms to short rotation forests cut for timber, firewood, and charcoal; from burned-over stands to mature forests increasingly fragmented by encroaching suburban development.

Most of the forests we see today in New England and New York are even-aged stands that originated during the period of heavy cutting and wildfires. The northeastern forest resource stands at the brink of a significant change in the relative mix, or balance, of species composition. Changes may happen because some species are favored and increase, or because other species are selected against and decrease. Some changes are the result of ecological succession, a progressive change from shade-intolerant species like aspen and gray birch to shade-tolerant species like maple, yellow birch, and beech. Succession occurs naturally in the absence of deliberate management or other external disturbance. Species-mix shifts may also result from human activity. When species are targeted for cutting without attention to their regeneration, the forest's productivity and diversity decrease. As an example of increasing abundance, a nonnative decline-disease complex of American beech increases the abundance of beech when mortality of large mature stems stimulates the reproduction of suckers from the root system to create beech shrub thickets. In warmer portions of the region, deer populations have grown to exceed the healthy carrying capacity of the forest. Deer prefer to browse species such as sugar and red maple, oaks, white pine, hemlock, basswood, white cedar, and white ash. The combined effect of selective cutting and overabundant deer causes stands to shift to a species mix more abundant in beech, red maple, and noncommercial species—all having lower economic value and fewer wildlife benefits.

Most of the forests we see today in New England and New York are even-aged stands that originated during the period of heavy cutting and wildfires.



As an ever-growing population demands an ever-increasing array of benefits from a privately held forest land base that is now decreasing in area, careful stewardship, including the need to be able to successfully regenerate the forest with desirable species, becomes ever more critical.

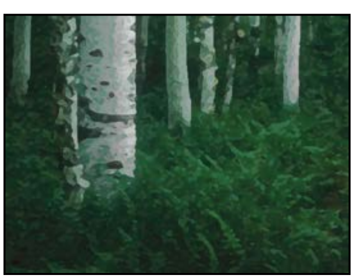
The change in forest composition is also the result of changes in the type and intensity of forest disturbance. The current oak forests, as well as the earlier chestnut, arose on lands that were burned and clearcut at short intervals. These species are well adapted for repeated disturbance, especially wildfire. Their thick bark protects mature trees from all but the most severe wildfires. In addition, they readily resprout after either being cut or top-killed by fire.

In contrast, wildfires frequently damage and kill thin-barked species such as birch, maple, and beech. Because these species, excluding beech, do not resprout as vigorously as oak, chestnut, and hickory, they are at a competitive disadvantage in stands repeatedly burned or cut for firewood and charcoal.

As with the shift from chestnut to oak forests at the beginning of the 20th century, the ongoing shift in forest composition will alter the economic, ecological, and esthetic values of the forest. In many cases, these changes in forest composition may reduce the economic potential and productive capacity of the forest, and the diversity of tree species available to serve human and wildlife needs. The consequences of such changes will last well into the 21st century. In southern New England, for example, oak is more economically important than maple and birch for its higher value (subject to the whims of furniture and cabinetry fashions), lower cull rates, and higher per acre volume growth. A shift from oak to other hardwoods will also affect many wildlife and insect populations—discriminating against those species dependent on oak and favoring those species associated with northern hardwoods. In New York and New Hampshire, the shift is from oak and sugar maple to red maple and beech. Although the species patterns differ, the consequences will be the same.

Changes in esthetic values are important because of increased public utilization of the forested landscape for both home sites and recreation. The leaves and flowers of maple and birch are more colorful than oak; however, faster growing oaks and pines are more likely to have the “big tree” characteristics that the public associates with mature forests.

Changes made to the land by modern society tend to be much more permanent than those made in the past. Cut-over, burned, or converted to pasture, the forest grew back quickly. The same cannot be expected from the conversions made to other land uses today, or given the barriers to regrowth associated with deer overpopulation or interfering vegetation that can dominate a site. As an ever-growing population demands an ever-increasing array of benefits from a privately held forest land base that is now decreasing in area, careful stewardship, including the need to be able to successfully regenerate the forest with desirable species, becomes ever more critical. Our society is poised at a unique moment in history with respect to the future of the forest resource, and the decisions we make today will affect whether many future generations will continue to enjoy the vast many benefits our forest resource provides.



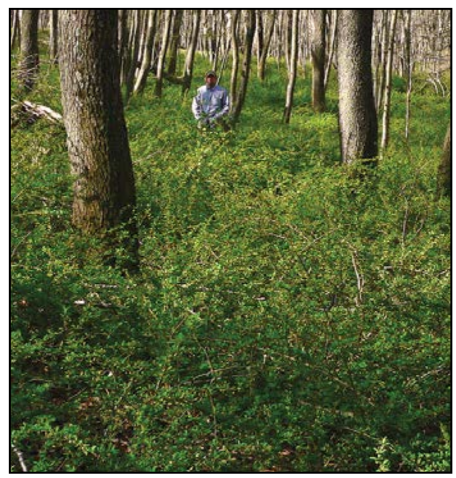
Challenges Today and Tomorrow

Landowners, professional foresters, and concerned citizens should be committed to sound forest management based on the best science available to avoid a return to the types of exploitive use of forests that were typical in the mid- to late 1800s and, unfortunately, continues to some degree even today. Five major challenges to forest management at the landscape level can be recognized in the Northeast: alien invasive species, coping with deer, fragmentation and parcelization, maintaining habitat diversity, and stewardship on private forest lands.

Alien (Nonnative) Invasive and Native Interfering Species

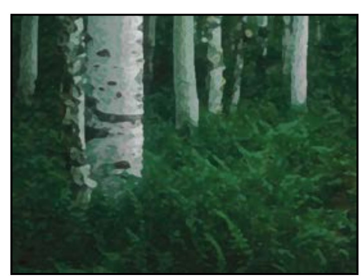
Alien invasive plants, insects, and pathogens have interrupted natural plant associations and ecology since the time of European settlement. Settlers imported some plant species from their homelands for their desirable characteristics and were unaware of their invasive potential. Other species arrived inadvertently, transported to the New World in household belongings or cargo shipments. The introduction of alien plants has not only caused the displacement of native plants, but also indirectly caused additional problems in some cases by bringing in alien pathogens and insects.

Invasive plant introductions continue today. Many well-intentioned landowners purchase plants from local or not-so-local vendors that, once established, can become aggressively invasive. Some portions of the region have areas ranging in size from acres to whole towns where invasive plants have almost totally displaced natural vegetation. Inaction is ecologically expensive and restoration is financially expensive. Everyone from landowners to tree planters, the nursery industry, and public officials needs to be made aware of problem species and creative solutions.



Invasive plants such as Japanese barberry can displace native species.

Alien insects and pathogens have already had a large impact in northeastern forests by nearly eliminating American chestnut and elm. Other species have also been adversely affected by insects and disease. Butternut has been reduced by a canker, and the tiny hemlock woolly adelgid threatens the region’s hemlock resource. Recent introductions edging into the region include the emerald ash borer and the Asian longhorned beetle, which threaten ash and maple, respectively. Extensive efforts are underway by Federal and State officials to eradicate alien species before they become established, reduce their spread, and discover effective control measures—thus reducing their impact on, and preserving the character of, our native forest ecosystems.



Other interfering species are native, but also create unfavorable conditions for regeneration of desirable species. These interfering native species include American beech, striped maple, eastern hophornbeam, numerous ferns, and some other herbs (Bashant and others 2005, Nyland and others 2006). In most cases, the resistance of these species to deer browsing has allowed them to dramatically increase and form dense patches that exclude more valuable species. In some cases, such as American beech, introduced diseases have changed the ecology of the species from a tree into a clonal shrub. In other cases, selective exploitive harvesting (high-grading) has created only small openings in the forest canopy that favor shade-tolerant understory species.

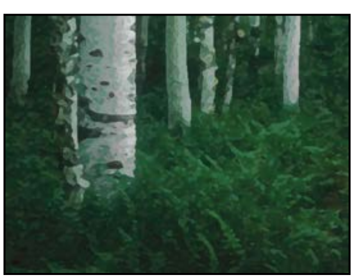
Coping With Deer

White-tailed deer are adaptable and can survive in all forests, young and old alike. Although there are programs to increase or maintain deer populations in northern New England where severe winter weather can increase mortality, that is not the case elsewhere in the region. High deer population numbers in southern New England and parts of New York have significantly altered forest structure, function, and appearance. Deer browsing affects regeneration, abundance, and distribution of species, particularly in regenerating stands or those in early stages of succession, where the forest floor is open to sunlight. Selective browsing of certain species by deer gives a competitive advantage to other species and can result in the complete elimination of some desirable species from the mix in a regenerating stand. These negative impacts are apparent for wildflowers as well as tree seedlings. Landowners and foresters should deliberately assess the potential of deer browse damage before carrying out any forest regeneration plan. Failure to do so could result in wasted investment or the loss of the seed source before a stand is successfully regenerated.

The deer issue often polarizes a community. To some, deer remain a symbol of nature and peace that necessitates protection. For others, they symbolize the destructive potential of wildlife on forest and landscape vegetation. Collisions with deer can damage vehicles and cause human injuries and fatalities; deer also enhance tick populations, thus increasing the prevalence of diseases such as Lyme disease, babesiosis, and human granulocytic anaplasmosis. Volumes have been written about the influence of deer on forests and strategies to minimize those impacts. Recent studies have found that high deer densities can increase densities of some invasive species.

Deer browsing inhibits forest regeneration in southern New England and parts of New York.

The impact of deer varies across the region, and even within a State. Deer population size cannot be the sole concern, because the actual impact of herd size depends on many other factors, such as the availability of alternative food sources and the duration and intensity of winters. All things being equal, deer in areas with alternative food sources, such as agricultural or suburban landscapes, will have less of an impact on forest regeneration than in areas of contiguous forest. Deer in northern and high-elevation climates with regular severe winters may experience winter kill that maintains and restricts excessive population growth. Instead of taking steps to limit their numbers, management is actively used to maintain or increase their numbers. Warmer areas proximate to urban centers where hunting is restricted often have significant problems with deer.



Minimizing the impact of deer requires either reducing the size of the deer herd or restricting its access to forest areas being regenerated. Cost-effective herd size reduction may occur through hunting, with an emphasis on reducing the percentage of female deer in the herd. However, hunting and other sources of deer mortality will need to reduce deer densities to fewer than 21 deer per square mile for native forbs and densities and fewer than 13 deer per square mile for adequate tree regeneration (deCalesta and Stout 1997). Hunting provides recreation as well as revenue-generating potential for communities. Restricting the access of deer to regenerating areas requires fencing off the area or, for quite small parcels and small numbers of seedlings, the use of tree protection devices on natural or planted seedlings. Woven wire, plastic mesh, and multistrand high-tensile fences have proven effective in some cases. The choice of fencing material depends on cost and the expected longevity of the need for the fence.

Minimizing the impact of deer requires either reducing the size of the deer herd or restricting its access to forest areas being regenerated.

Fragmentation and Parcelization

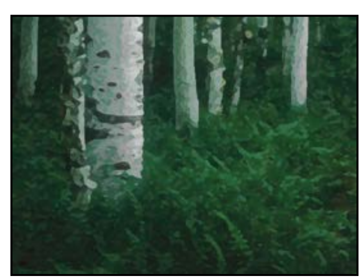
A major issue plaguing the forest resource of the Northeast is population growth and the associated loss of forested open space to residential development. In our steadily suburbanizing region, privately held land can be subject to change in ownership and use at any time. Changes in use and ownership can affect all members of the community and should be planned, or at least anticipated, in order to minimize the impact to both human and forest communities. Through a detailed inventory and analysis of natural resources in a community, local planners and decisionmakers can obtain the data they need to make effective, high-quality plans for conservation and development that will guide future growth. The key to effective planning is to identify areas most suited to development and direct growth to those areas, while concurrently identifying and carrying out protection strategies for key natural resource features.

Fragmentation and parcelization of forest land are of concern to regional planners.

Recognizing the important role that upland forests play in protecting water quality, wetlands, and other habitat features, community leaders can justify the effort necessary to determine the extent and distribution of forested land and identify sensitive areas that may be threatened by development.

Maintaining Habitat Diversity

In recent years, sporadic controversies have arisen over forest harvests with significant visual impact, especially even-aged forest management practices such as clearcutting. One consequence of the public debates regarding even-aged management is that landowners, local regulators, and foresters are favoring partial cuts over longer rotations (uneven-aged management). Uneven-aged management usually has significantly lower visual impact than even-aged management. Studies indicate that partial cutting may accelerate the pattern of red maple and beech replacing oak in the southern part of the region and sugar maple



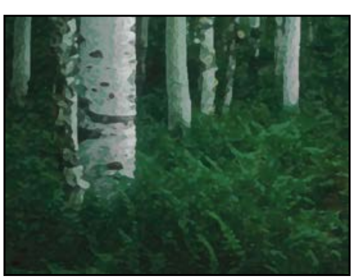
in the northern part. Because forest growth and development is a long-term process, management decisions today have real long-term consequences. As mentioned previously, these changes will affect not only the quality and makeup of forest products and recreation opportunities available to future generations, but also the quality and variety of wildlife habitats.

The importance of the early successional habitat found in seedling and sapling stands to numerous plant and animal species is not well appreciated by the general public. As noted by DeGraaf and others (2005), early successional habitat is crucial for species such as whippoorwills, New England cottontails, and eastern bluebirds. In addition, many valuable tree species such as oak, pine, and aspen need higher levels of light to develop into saplings than are commonly found in forest preserve and partially cut stands. While it is common to find small oak seedlings, especially after a heavy mast year, oak saplings are rare. Many native grass and herbaceous species also depend on early successional habitat to maintain their populations. Even-aged forest management practices, or the more expensive alternatives of periodic mowing or brush cutting, are required to maintain a portion of the landscape in early successional habitat.

The Northeast has lost hundreds of thousands of acres of these valuable early successional habitats, which is attributable to three factors: (1) These habitats are ephemeral. They were uncommon in pre-settlement forests and shifted across the landscape following natural disturbances such as severe storms and beaver dams. The very nature of plant and tree growth causes them to grow to more advanced successional stages. (2) Fewer farm fields are being abandoned, and those that are abandoned are often converted to residential or commercial development, or are colonized by nonnative plants. (3) As noted previously, partial or "selective" cutting that perpetuates a tall, though less diverse, forest has become the most common forest management practice in the region. While it is unlikely that early successional habitat will completely disappear, it would be worthwhile to determine the critical minimum amount of early successional habitat required to maintain healthy populations of early successional species.

Stewardship on Private Lands

Stewardship ensures that the consumptive and amenity values and benefits enjoyed today will remain available for future owners, neighbors, communities, and industries. Therefore, stewardship will be a primary objective for many landowners and hopefully supported by local land use officials and forest practitioners. Seventy-three percent of the region is forested; of that, approximately 54 percent is in private, nonindustrial ownerships. Some private lands are managed by land trusts, small water companies, camps, and sportsmen's organizations; however, the bulk of private landowners are individuals, families, and farmers. While forest land ownership patterns and owner's goals are varied, diverse, and complex, there are some emergent trends and identifiable patterns that may provide an indication about the long-range future of the forest resource.



Forest lands are becoming increasingly parcelized. Although the amount of forest land has remained remarkably stable over the last 30 years, the number of different owners has increased dramatically. As ownership changes hands, large parcels are often divided into pieces that are still technically forest land, but are economically and logistically "unmanageable." Owners of small parcels may have difficulty finding technical service providers, appropriate educational resources, access to cost-share programs, and strategies to work cooperatively with a relatively high number of neighbor issues.

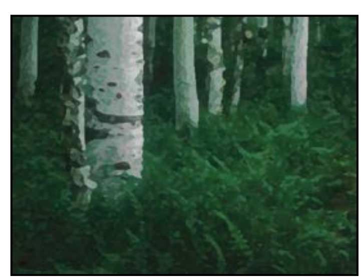
Stewardship ensures that the consumptive and amenity values and benefits enjoyed today will remain available for future owners, neighbors, communities, and industries.

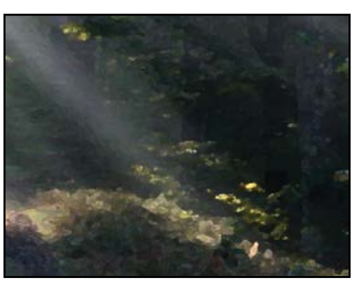
Landowners are aging, and many parcels will change hands in the next 15 years. The average age of forest landowners of parcels greater than 10 acres is in the early sixties (Butler 2013). When current owners end their tenure, property is either sold or transferred to other family members. This process contributes significantly to parcelization, leading to fragmentation of the resource. Landowners who desire a sustained influence on how their land is managed should invest time and resources into the legacy of their property. Tactics to sustain influence range from a nonbinding understanding with the future heirs to a comprehensive conservation easement that becomes part of the property deed.

Forest landowners provide many public benefits yet receive little, if any, compensation. The public enjoys many benefits derived from private forest lands at no cost (high-quality water, cleaner air, wildlife habitat, and esthetics, for example) and often takes them for granted. In return, the people who own and manage the resource have limited access to a small number of public programs that support forest stewardship, such as State-level forest land tax abatement and Federal-level cost-share programs.

Few, if any, financial incentives exist for holding forest land, except forest products. Landowners often hold forest land for reasons other than the promise of economic return, but some economic return is often necessary in order to keep the land "intact." Forest ownership incurs obligatory expenses such as property taxes and insurance, and variable expenses related to property management. Trees sold as raw material for forest products are often the only potential source of financial support for the land. Less common sources of income from forest land include leasing to hunters, maple syrup production, and agroforestry specialty crops such as blueberries, ramps, mushrooms, and fiddleheads.

Managing the forest for periodic income from the sale of trees as raw materials for forest products *depends* on being able to regenerate the forest successfully. When trees are harvested, the ability to replace them naturally with a desirable mix of healthy and productive seedlings maintains the value of the forest. Therefore, landowners who manage for timber income, loggers, and other forest practitioners who depend on a gradually shrinking land base for their livelihood need to be invested in ensuring successful, desirable regeneration. Market forces typically do not favor these investments and may be a disincentive for sustainable management.

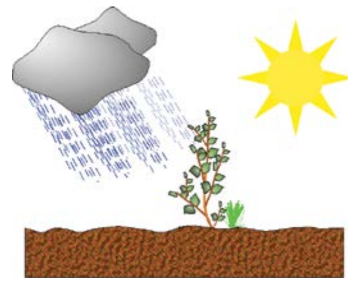




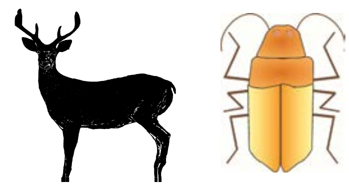
Section II: Environmental Factors

Trees can survive and grow under unique and often stressful combinations of environmental conditions (e.g., light, moisture, soil, and space). Different species of trees require different combinations of these factors, depending on their particular adaptations. Healthy, productive stands occur where the environmental conditions available match the optimum growth and development needs for the species mix present.

Tree establishment and growth are influenced by two types of factors—**abiotic** (nonliving, or environmental, factors such as light, moisture, and soil) and **biotic** (living factors such as insects, disease, browsing, and competing vegetation). This section discusses abiotic, or environmental, factors.



Abiotic (nonliving) factors



Biotic (living) factors

When one or more necessary environmental factors are in short supply, the growth and development of trees and stands (relatively homogeneous groups of trees) are affected. In stands where a serious soil moisture shortage exists, for example, increasing the abundance of light, space, or soil nutrients would not likely increase stand growth. As soil moisture is increased, however, a corresponding increase in the growth and development of the stand could be expected until some other factor becomes limiting.

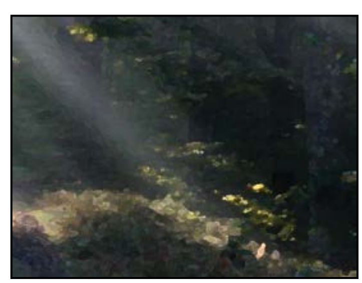
Trees change in their sensitivity to environmental factors as they mature. Young seedlings in their first and second years may easily succumb to drought stress, browsing, root pathogens, and low light conditions. As seedlings develop, they accumulate energy reserves that allow them to compensate for changing environmental conditions, and balance the demands of the leaves with the root system's ability to collect moisture and nutrients.

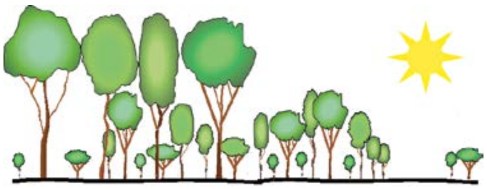
The manner in which environmental factors influence seedlings will determine the ability of seedlings to germinate, become established, survive, and grow. Among the factors affecting growing conditions at any site, the one that, if changed, will result in the greatest corresponding increase in productivity of the stand is commonly known as the "most limiting factor."

Light

All growing plants require sunlight for photosynthesis…trees included! For most northeastern tree species, adequate light is the most critical factor to successful regeneration. Species that compete best in full sunlight have the capacity for rapid height growth and are often found in the upper layers of the forest canopy. Species that are able to compete in the shade of other trees can occupy lower layers in the canopy.

The minimum amount of light required for optimum growth and development (or even survival) varies significantly among tree species. The relative ability of a plant to grow beneath overtopping vegetation is known as "shade tolerance" (see graphic on following page). The shade tolerance of seedlings is a key characteristic affecting their development. A shade-tolerant species endures, but does not necessarily thrive in, low light conditions.

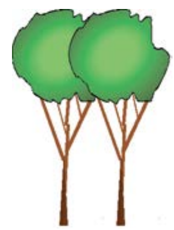


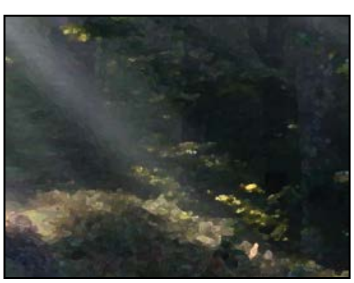


Each canopy layer intercepts light before it reaches growing seedlings.

For most plants, photosynthetic production, the plant's source of energy, improves with modest increases in light. Disturbance that increases sunlight on the forest floor will stimulate regeneration. When management objectives call for regenerating a mature forest, foresters prescribe harvesting systems to control the light availability that reaches the forest floor, depending on the desired mix of seedling species.

Shade Tolerance

Intolerant	Midtolerant	Tolerant
		
Needs full sunlight	Grows in partial sunlight	Endures forest shade
Common Tree Species		
Yellow-poplar Paper and gray birch Bitternut and mockernut hickory Aspen Ash Pin cherry	Red, black, and scarlet oak Shagbark hickory White and chestnut oak Eastern white pine Black and yellow birch Blackgum	Hemlock Sugar, red, and striped maple Beech Basswood Spruce
Species Characteristics Analogy		
High stakes gambler Fast growth rate Few reserves Short lifespan High mortality	*Investor* Moderate growth Some reserves Medium lifespan Moderate mortality	*Miser* Potentially slow growth rate Large reserves Long lifespan Low mortality



Moisture

Each species has adaptations for distinct moisture regimes. Some species have adapted to extended periods of drought (e.g., pitch pine, chestnut oak); others have adapted to extended flooding (e.g., silver maple, pin oak). Most species grow in the middle of the continuum between very dry and very wet soils; our most valuable timber species thrive best on moist, well-drained soils. Seedlings of any particular species have a well-defined range of soil moisture in which they have the greatest competitive advantage.

Forests have a remarkable capacity to absorb moisture from precipitation, regulate stream flow, and clean water as it moves through the forest ecosystem. Forests excel at protecting water quality compared with other land uses. An understanding of the interactions between the forest soil, moisture, and seedlings when forest stands are harvested for regeneration starts with an examination of how forests and water interact in undisturbed environments.

Forests have a remarkable capacity to absorb moisture from precipitation, regulate stream flow, and clean water as it moves through the forest ecosystem.

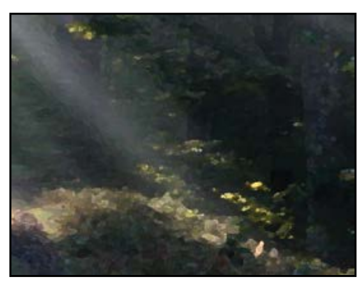
Up to one-third of the precipitation that falls on an undisturbed forest never reaches streams and underground aquifers. Some is caught on leaves and branches and evaporates. Some of the precipitation that reaches the ground is absorbed by tree roots and is eventually transpired into the air through the leaves. Together these processes are known as evapotranspiration.

The undisturbed forest floor, consisting of a thick layer of leaf litter on top of loose friable soil high in organic matter and securely bound by tree roots, has a tremendous capacity to absorb rainfall. Overland flow or runoff is a rare event, and erosion is virtually unheard of in undisturbed forests. Instead, clean water gradually percolates through the soil to the groundwater, and eventually emerges in streams, ponds, and wells.

Soil—Back to Our Roots

Soil characteristics parallel the importance of canopy disturbance in influencing forest composition. Not all soils are the same; in fact, it is amazing how many different soil types there are, each with its own defining characteristics. The mix of soil fertility, moisture, depth, and texture determines whether a particular species will thrive on any given soil.

A variety of soil nutrients must be present in available form for seedlings to be successful. Elements such as carbon and nitrogen usually cycle through the organic material present in the forest, while potassium and phosphorous come from the mineral portion of the soil. Seedlings also require a variety of minor nutrients such as calcium, iron, and sulfur. Each plays a role in the life cycle of the tree and must be present for survival and successful growth. In short supply, one or more nutrients can be the limiting factor to the growth and development of trees or stands. Trees may survive in the absence of an essential element, but some tree processes, such as flowering or resilience to pathogens, may be compromised.



Taken together, the root systems of trees in the forest comprise a complex, dynamic, interwoven carpet of live woody tissue in the upper layers of the soil.

Taken together, the root systems of trees in the forest comprise a complex, dynamic, interwoven carpet of live woody tissue in the upper layers of the soil. Ninety percent or more of tree roots are found in the top foot of soil because roots need oxygen to survive. Spring and fall are the most active periods of root growth.

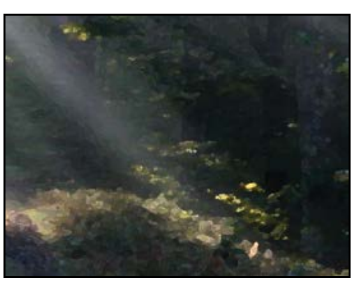
The root systems of trees provide four essential functions: (1) anchorage or support, (2) storage of nutritional compounds, (3) absorption of water and nutrients, and (4) conduction of water and nutrients. Mature plants have larger storage roots that support survival, while seedlings have finer, more delicate roots. Once seeds germinate and the seed leaves (cotyledons) wither, seedling survival depends on the roots being in a favorable location, accessible to soils that provide adequate stability, oxygen, moisture, and minerals.

For some species, even a slight disturbance of the forest floor that exposes some mineral soil and mixes organic matter into the seedbed can enhance conditions for successful germination. However, because most roots are near the soil surface, they are susceptible to damage from heavy equipment, especially when soils are wet. The roots of seedlings are especially sensitive.

Because most roots are near the soil surface, they are susceptible to damage from heavy equipment, especially when soils are wet.

In some areas, populations of exotic earthworms are altering natural forest processes, including soil-water relationships. Most earthworms in the Northeast are alien invasive species, having arrived in forests through various and not completely understood events that may include agriculture and sport fishing. Increasing earthworm populations can accelerate the decomposition of leaf litter, leaving otherwise undisturbed forests without a thick spongy mantle of humus. The disruptions and consequences of alien earthworms on our forests remain under investigation.

Site Quality—Putting It All Together



The natural vegetative cover for most of the Northeast is forest of one type or another; however, some sites are better for growing forest trees than others. Tree growth is a function of the genetic potential of a species interacting with the environment in which the tree is located. Environmental factors associated with topography, moisture, soil fertility, and drainage are collectively known as site quality. Sites that have adequate but not excessive moisture and abundant available mineral nutrients are considered “good,” while sites with moisture or fertility characteristics that limit growth would be considered “poor” (see graphic on following page).

Less obvious, perhaps, is the fact that environmental conditions considered favorable for the natural growth of one species may be unfavorable for another, so any discussion of site quality must be made in the context of a particular species or species mix (forest type). Most species thrive in fertile, moist, well-drained soils. However, which species are found on a given site will depend on their efficient use, or toleration, of suboptimum environmental conditions (e.g., scarce minerals, semisaturated soils, low light). For example, scarlet oak grows best in moist, well-drained soils, but is usually found on dry ridges because of its ability to tolerate dry soils. It should be noted that for a given species, the optimal site will vary from southern New England north to the Adirondacks and Maine (table 1). Eastern hemlock is common on ridgetops and south-facing slopes in the north, but is more often found in coves and north-facing slopes in the south.

Table 1. Typical soil types for various species in New Hampshire

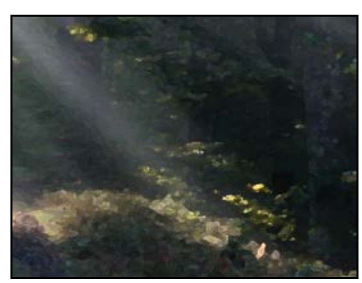
Species	Soil drainage class
White ash, sugar maple	Moderately well-drained
American beech	Sandy tills
Northern red oak	Sandy tills and outwash
Eastern white pine	Outwash and sandy tills
Red spruce, balsam fir	Poorly drained shallow fragipan

Site Quality and Topographic Position

Poor sites have low fertility and dry soils. They are commonly found on ridgetops, swamps, and where soils are very sandy.

Average sites have intermediate soil moisture and fertility. They are commonly found on hillsides.

Good sites have high fertility and abundant soil moisture. They are commonly found in valleys and lower slopes or benches on hillsides.



Following a disturbance and colonization of a site by plants, conditions change rapidly within a forest stand during early stand development as individual stems compete for space.

Early Stand Development—Competition for Space

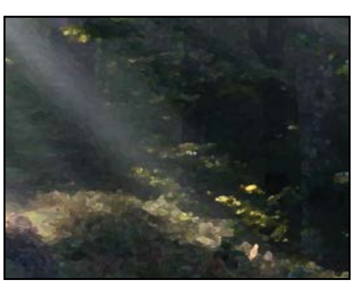
Following a disturbance and colonization of a site by plants, conditions change rapidly within a forest stand during early stand development as individual stems compete for space. The success or failure of achieving desirable regeneration rests on the stems' ability to overcome certain barriers or bottlenecks. These bottlenecks can be categorized according to the period of early stand development during which they have the most influence on the desired regeneration species.

Prior to harvesting, mature and well-tended forests typically have 5,000 to 12,000 seedlings and saplings per acre. The density of the seedling layer, those stems less than 1 inch in diameter at 4.5 feet above ground, can range from 30,000 to 200,000 stems per acre several years after harvesting. These estimates do not include untold numbers of shrubs, ferns, grasses, and herbaceous plants. Years after the overstory is removed, when the young canopy begins to close and crown classes can be distinguished, fewer than 2,000 stems per acre are likely to remain in the upper canopy of the new stand.

Stand Initiation

The timing of a harvest, the provision for a reliable and desirable source of seeds or sprouts, the preparation of a suitable seedbed, the control of deer impacts, and the control of interfering vegetation are factors that must be incorporated into a management system to successfully regenerate stands consistent with the landowner's objectives. The potential for success of new seedling establishment diminishes with each year after harvest as other plants occupy the site. When the site is fully occupied several years later, any new seedlings are unlikely to be competitive with older seedlings, sprouts, and herbaceous plants.

For most species, successful regeneration after stand initiation originates naturally from one of four sources: germinating seeds, advanced regeneration (larger, established seedlings), stump sprouts, or root suckers. Successful natural regeneration depends on the availability of a nearby seed source for the desired species or a sufficient number of stump sprouts, advanced regeneration (especially for oak), or root suckers. As a rule of thumb, the older the trees are when harvested, the less their ability to produce stump sprouts or root suckers. Therefore, following harvesting in mature stands, regeneration of desired species is not likely to occur without a reliable source of seeds or presence of advanced regeneration. Equally important, some trees (e.g., aspen, black birch) produce large numbers of wind-dispersed seeds, whereas other species (e.g., oak, beech) produce smaller quantities of seeds dispersed by birds and mammals. It is very important to remember that when the overstory of a stand is only partially removed, the remaining trees that cast seed and any existing understory trees will drive the composition of the new forest.



Seedling Establishment

During the 3 to 4 years following that critical first growing season, seedlings in the young stand must compete with each other and with other vegetation for light, moisture, and nutrients. Regeneration density will peak during this period, with tens of thousands of stems per acre. Microsite conditions, weather or mechanical damage, deer browse, and other factors all conspire against young trees, resulting in very high rates of natural mortality. The result is that only a small percentage of seedlings actually survive and develop into saplings.

Seedlings undergo dramatic root and branch development. Competition during this stage is often a race to physically occupy horizontal and vertical growing space, both above and below ground. Once the space is fully occupied, the stand enters the next stage of development.

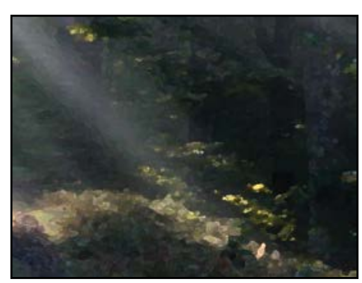
Crown Closure

Trees that are present in the main canopy at the time of crown closure result from seedlings that have germinated successfully, become established, and have had sufficient space to grow and develop competitive branch and root systems. Freedom from competition for space (free-to-grow status), even more than the rate of height growth, is the primary factor in the success of an individual tree achieving dominant or codominant position in the main canopy. Those saplings present in the upper canopy and receiving full sunlight at the time of crown closure have the best potential to remain in the upper canopy (and develop into valuable sawlogs) when the forest matures.

Freedom from competition for space (free-to-grow status), even more than the rate of height growth, is the primary factor in the success of an individual tree achieving dominant or codominant position in the main canopy.

During this time, the individual trees having the best ability to compete become the dominant trees in the stand, while slower growing or defective trees become overtopped. Eventually the branches of saplings that are dominant in the stand begin to encroach upon each other's space, forming a continuous canopy. This stage in the development of the stand, known as crown closure, is usually apparent by the time the stand has reached a height of about 25 feet.

Those saplings present in the upper canopy and receiving full sunlight at the time of crown closure have the best potential to remain in the upper canopy when the forest matures.



Section III: Disturbance—The Agent of Change

Changes in forest composition result from variations in the type, intensity, extent, and frequency of forest disturbance.

Since the receding of the glaciers at the end of the last Ice Age in North America 10,000 to 12,000 years ago, natural and human-caused disturbances, such as ice and windstorms, floods, fire, and clearing, have played a critical role in the establishment, growth, death, and reestablishment of forests. Forests are not static dioramas. Trees grow, reproduce, and eventually die. Catastrophic disturbances create the conditions necessary to perpetuate pioneer species and early successional habitats. Minor disturbances permit a diversity of age structures and opportunities for species that can compete in partially shaded environments.

In forest preserves, where disturbance is limited to small gaps created by single- or multi-tree mortality, species able to establish and grow in forest shade, such as maple, beech, and hemlock, are favored. Higher levels of light than are commonly found in forest preserve or partially cut stands are needed for seedlings of many species to develop into saplings, e.g., oak, cherry, paper birch, and aspen. Thus, managing a forest as a preserve is an active decision for a gradual conversion to a forest with more beech, and maple if deer impacts are limited. Without proactive forest management (or a major hurricane!), many valuable and esthetically pleasing species will gradually disappear from our forests.

Changes in forest composition result from variations in the type, intensity, extent, and frequency of forest disturbance. Harvesting trees for forest products constitutes disturbance, and because tree species have adapted to regenerate successfully under certain disturbance conditions, harvesting methods are often designed to mimic natural disturbances that favor certain species.

There is, however, one important distinction between a natural disturbance and a timber harvest. When a harvest is planned, **the forester has control over which trees are cut and which trees are left**. The success of regeneration and the future condition of the forest is affected more by what is left than by what is harvested from a stand. Thus, it is of critical importance to the future species mixture, health, and productivity of the forest that the person making these decisions be knowledgeable about species' requirements for successful regeneration and apply this knowledge in a manner consistent with the landowner's objectives.

Sound forest stewardship is a true intergenerational commitment based on the concept that rather than having inherited the resource from a previous generation, we are borrowing it from a future one. The forests we enjoy today originated by the deliberate actions of previous generations within the biotic and abiotic conditions of the time. Decisions made by landowners, foresters, and public officials today will affect the composition and habitat diversity of forests that will be enjoyed by generations yet unborn.

Understanding how species respond to the type, intensity, and frequency of disturbance allows foresters to prescribe harvests that ensure successful regeneration.

Mimicking Natural Disturbance

As any avid gardener knows, each plant species is adapted to thrive in a specific, optimal range of soil moisture, fertility, and climate. This concept logically extends to trees. Atlantic white cedar is found in swamps with high water tables and chestnut oaks dominate dry ridges because each species has the ability to compete in those environments. Pitch pine is endemic to sterile sandy soils, while optimum sites for sugar maple are rich, loamy soils with high fertility.

Less well-appreciated and understood are the adaptations forest trees have to different disturbance regimes. Disturbance regimes are determined by the relative combination of three disturbance components—type, intensity, and frequency—and typically occur as either small scale and frequent or large scale and infrequent. Disturbances often affect a specific height class of stems in the forest.

Properly conducted, most harvesting methods mimic a natural disturbance.

Properly conducted, most harvesting methods mimic a natural disturbance. Humans have the advantage over natural processes to plan specific disturbance events and their impact. A forester should first determine the landowner's long-term management goals, inventory the forest resource, and then incorporate this information into a management prescription. An integral part of the management plan is to determine a species mix that matches site conditions and best achieves those goals. Understanding how species respond to the type, intensity, and frequency of disturbance allows foresters to prescribe harvests that ensure successful regeneration. If the desired species possess strategies for more than one disturbance regime (e.g., northern red oak, aspen), the forester can suggest alternative management prescriptions to the landowner.

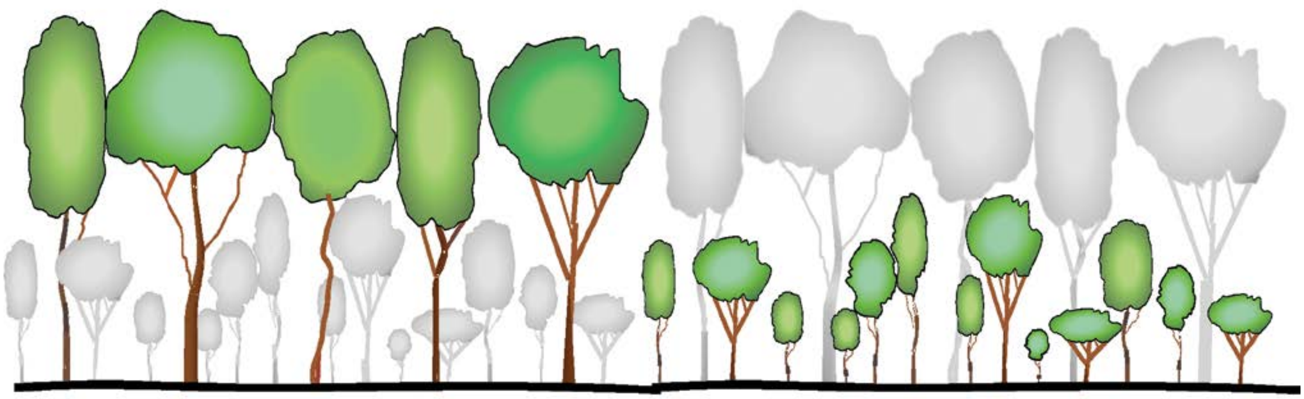
Disturbance Type

The type of disturbance occurring in a forest stand directly affects the survival of regeneration. Disturbance types may vary from those that remove only the smallest trees in the understory, such as controlled grazing in a stand or a low and fast-moving fire (low disturbance), to those that remove predominantly the largest trees in the stand, such as a severe ice or windstorm (high disturbance).

A low, or understory, disturbance increases the amount of sunlight (ambient or filtered) available to seedlings by removing the shade cast by saplings and small trees. The impacts of low disturbances on soil moisture, temperature, and exposure depend on the cause of the disturbance.

High winds that topple overstory trees are an example of high disturbance.

A high, or overstory, disturbance increases the amount of direct sunlight that reaches the next highest layer of vegetation, potentially leading to an increase in light availability and soil temperatures at the forest floor. High disturbances will often increase mineral soil exposure as many trees are uprooted. Since a forest can transpire the equivalent of an inch of precipitation a week, soil moisture will also increase temporarily for a period of several years when the overstory is removed by harvesting or destroyed by a windstorm.



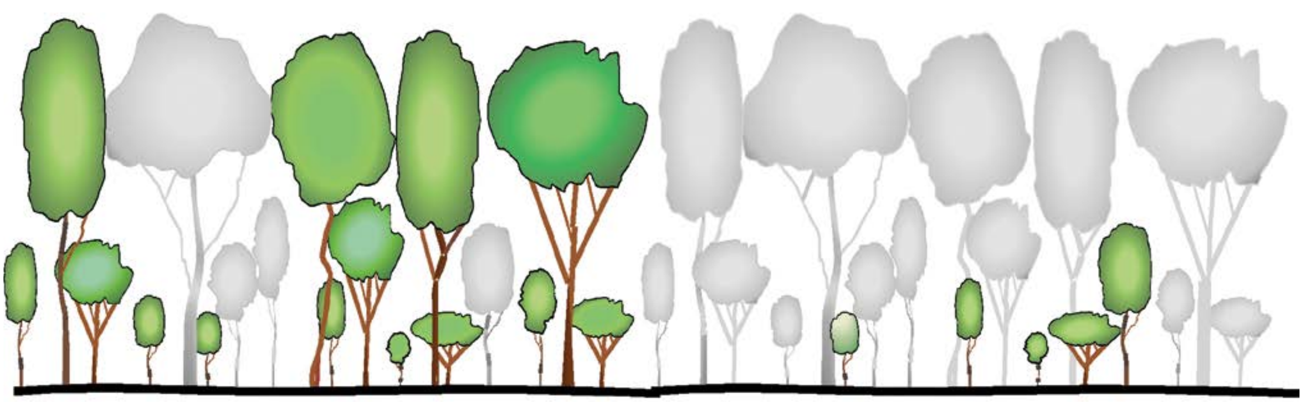
Low (understory) disturbance High (overstory) disturbance

Disturbance Intensity

Disturbance intensity affects the success of regeneration through its influence on environmental factors. Whether windthrow or mortality results in the loss of a single tree or a large group of trees in a given stand, seedlings will become established and grow in the openings left behind. The species that survive and continue to grow vary depending on the species present or available, the intensity or size of the disturbance, the resulting opening, and other factors previously discussed. Disturbance intensity and extent defines the amount of sunlight available to seeds and seedlings.

Slow, gradual mortality of individual trees (single tree disturbance) favors shade-tolerant species that can germinate and become established in the undisturbed leaf litter of the forest floor and compete in the presence of a mature overstory (e.g., sugar maple, beech). A storm microburst that uproots a small group of trees gives the advantage to species that can become established in partial to full sunlight and may be more competitive where some bare mineral soil is exposed (e.g., black birch, red maple).

A high-intensity (stand replacement) disturbance, such as a severe ice storm or clearcut, favors species that are adapted to full sunlight for best development (e.g., aspen, pitch pine). These species are unlikely to be able to compete unless an intense disturbance removes both overstory and understory trees. Other species that are more shade tolerant and also present as advanced regeneration will generally benefit as well if they survive the disturbance, since light is most often the limiting factor even for shade-tolerant species.



Single tree disturbance

Stand replacement disturbance

Disturbance Frequency

The frequency of forest disturbance can vary from yearly (single tree mortality), to decadal (some insect outbreaks, ice storms, drought), to once a century (hurricanes). Indeed, many of the stands in public forests are currently managed on 100- to 200-year intervals between regeneration harvests. While this is similar to the return cycle for major hurricanes in southern New England, it should not be construed as advocating forest practices that would "mimic" effects on the scale of a major hurricane. Such disturbances will occur at natural intervals, regardless, and do not need to be replicated.

In contrast, forests in southern New England burned an average of once every 7 years prior to the 1920s. In the northern part of the region, fires were much less frequent because of more plentiful rainfall. Before modern forestry practices became widespread in the early 1900s, many stands were cut every

30 to 60 years for firewood and charcoal production. Frequent cuttings in younger stands of dense saplings and poles for fuelwood or pulp certainly favors those species that can regenerate rapidly from root or stump sprouts, such as oak, aspen, and some shrub species (e.g., blueberry).

Species that compete well as seedlings and saplings in partially shaded conditions, such as red maple and black birch, may benefit from disturbances every decade or so in which the upper canopy is "reopened" in stages as the mature forest is removed. Examples of disturbances that occur with intermediate-term frequency include drought, ice storms, and partial cutting.

Unmanaged stands in which disturbances of large extent do not occur for long periods of time ultimately tend to be comprised of mostly shade-tolerant, slow-growing species with long lifespans. These species, such as hemlock, beech, and sugar maple, create thick, dense canopies that prevent sunlight from reaching the forest floor, holding in the soil moisture and effectively out-competing shade-intolerant species.

A disturbance such as drought may occur every decade.

Forests in southern New England burned an average of once every 7 years prior to the 1920s.

Section IV: Forest Management for Regeneration

Forest regeneration methods are based on three premises: (1) Natural disturbances vary in type, intensity, frequency, and scale. (2) Different species are adapted to regenerate under different disturbance regimes (with different light levels and soil disturbance). (3) Cutting trees in the forest is a disturbance that can replicate these regimes.

Selecting the Best Silvicultural System for the Site

It stands to reason that for a harvesting method to result in successful regeneration of a desirable species mix, it should most closely mimic the natural disturbance regime for which the desired species are adapted. Additional cultural treatments may be necessary to reduce the abundance of other species not desired in the future stand. Because many species possess adaptations for more than one disturbance scenario, they can be expected to have some success regenerating under more than one, or a combination of, harvesting methods. Thus, the ecological characteristics of the species, the characteristics of the site and other pragmatic constraints of the property, and the goals of the landowner should be examined together to find the most feasible disturbance regime, simulated through cutting or other treatments, to ensure regeneration.

Management Objectives

The long-range management goals and objectives for a forested parcel, as identified by the landowner, should guide management recommendations. When planning a harvest to achieve one of the landowner's objectives, the forester should recommend and implement a harvesting method consistent with natural disturbance regimes for which the desired regeneration species have adapted. If the disturbance—in this case, harvest—is compatible with the ecological characteristics of the species, the target species and associated species will be more likely to respond as planned (table 2).

Examples of management objectives for any parcel of forest land could simultaneously include the following:

- Maximize periodic income from forest products
- Maximize habitat value for game or song birds
- Increase recreational value
- Preserve privacy and esthetic values

Readily apparent even from this partial list is that two or more of these objectives can be achieved with an appropriate management prescription, although some might not be compatible with others within the same stand of trees or even on the same forested tract. Therefore, the management objectives and priorities for each stand must be clearly stated so the owner and forester can consider the consequences of different harvesting methods on specific ownership objectives.

Table 2. Species groups that benefit from various types of silvicultural systems

Silvicultural system	Species groups
Uneven-aged silvicultural systems (e.g., single-tree selection, group selection, forest preserve)	**Trees**: sugar maple, American beech, black and yellow birch, eastern hemlock, basswood, pignut hickory **Shrubs**: flowering dogwood, mountain laurel, hobblebush, striped maple, witchhazel, ferns **Wildlife**: pileated woodpecker, flying squirrels, Acadian flycatcher, cerulean warbler, scarlet tanager
Even-aged silvicultural systems (e.g., shelterwood, clearcut, reserve tree)	**Trees**: oak, eastern white pine, black cherry, paper birch, white ash, yellow-poplar, aspen, eastern redcedar **Shrubs**: beaked hazelnut, sheep laurel, staghorn sumac, blackberries, blueberries, sweet fern, huckleberries **Wildlife**: red-tailed hawk, indigo bunting, white-tailed deer, eastern bluebird, cedar waxwing, New England cottontail

Factors Affecting Regeneration

Three factors largely determine the success of efforts to regenerate a forest.

1. **The correct silvicultural system ensures that seeds or sprouts from desired species are available and that those seeds have adequate sunlight and seedbed conditions** (table 3). Historical disturbances, either natural or human-induced, may have changed the nature of the forest. These changes may require extra steps to ensure the abundance and vigor of species desired for the next forest.

2. **Competing plants can overwhelm seedlings and must be controlled**. A variety of native plants (e.g., hay-scented fern, American beech, striped maple, and grass) and nonnative plants (e.g., buckthorn, barberry, and honeysuckle) can form understory layers sufficiently dense that they prevent desired species from thriving. These interfering plants may provide habitat for rodents that eat seeds, form dense root layers through which seedlings cannot compete or penetrate, or form dense shade that stresses seedlings. A forester should be able to assess the levels of interfering vegetation and make recommendations on appropriate control measures.

3. **Protecting seedlings from deer will allow growth of seedlings beyond browsing heights**. Deer impacts can vary locally, depending on deer herd size and alternative sources of browse. If deer are browsing forest regeneration, strategies to control the deer herd or to protect the plants, or both, must be used to ensure regeneration success. High deer densities can exacerbate formation of invasive shrub thickets or lead to the development of an impenetrable carpet of ferns.

Table 3. Environmental changes anticipated under various silvicultural systems

Silvicultural system	Anticipated environmental changes
Forest preserve	No immediate changes anticipated from human activity.
Single-tree selection	Small, scattered canopy gaps. Slight increase in filtered sunlight to forest floor. Minimal forest floor disturbance.
Group selection	Gaps in canopy of a width equivalent to the average height of the stand or more. Almost full sunlight conditions near the middle of gaps. Some disturbance of the forest floor in gap areas, minimal disturbance in the surrounding area.
Shelterwood system	Significant and evenly distributed disturbance of the upper canopy. Light and temperature increase at the forest floor. Moisture increases in the upper layers of the soil may be observed in the first one or two growing seasons following treatment. Disturbance to the forest floor is readily observable. Some mineral soil will be exposed and mixed with organic material.
Silvicultural clearcut	The entire upper canopy is removed, allowing 100 percent full sunlight conditions at the forest floor. Temperatures at and near the forest floor will increase dramatically. Low temperatures will also be more extreme. Wind conditions will be more variable. Soil moisture increases will be observable in the first several growing seasons.
Reserve tree	Most of the upper canopy is removed, creating light conditions intermediate to a shelterwood and clearcut. Temperatures at and near the forest floor will increase moderately. Wind conditions will be more variable. Disturbance to the forest floor is readily observable with some mixing of mineral soil with organic material. Soil moisture will increase for several growing seasons

Protecting Soil and Water

Protecting the soil to ensure good water quality during any forest management practice is a moral obligation, good business practice, and in most places, a legal requirement. Every forest management activity must be conducted in a manner that does not result in excessive detrimental disturbances to the forest soil. Soil disturbance associated with poorly constructed roads and trails creates the potential for erosion and sedimentation. A variety of techniques called water quality best management practices (BMPs) should be designed by foresters, implemented by loggers, and maintained by landowners to ensure that soil disturbance does not lead to erosion problems.

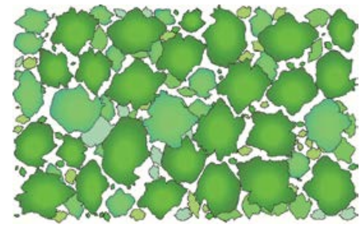
Properly conducted harvesting operations will not only control the amount of sunlight reaching the forest floor, but leave the stand with soil conditions that are ideal for promoting successful regeneration. Examples of good practices to protect forest soils include restricting harvesting equipment to designated skid trails, closing harvests during spring and early summer when soils are saturated, planning skid trails to minimize soil disturbance and maximize efficient operations, regularly inspecting harvesting operations to ensure crews follow guidelines, and installing water control structures during and after harvest to minimize sedimentation.

Types of Silvicultural Systems

On the following pages are descriptions of different silvicultural systems, or harvesting and regeneration methods, that are commonly prescribed in the Northeast, comparing them to the natural disturbance regimes they mimic. A comparative listing of management objective considerations is also provided. This listing may be viewed as pro/con or advantage/disadvantage, but that judgment must be made within the context of clearly stated management objectives and site-specific constraints.

This manual is not intended to be an instructional text in the application of silvicultural techniques in the field, but rather an explanation of the rationalization behind certain forest management practices. **The "how to" should be left to a qualified professional forester**. In some States, the law requires that only certified or licensed foresters prepare and apply silvicultural prescriptions.

Forest Preserve or Unmanaged Forest



Forest preserves, despite the lack of harvesting, are not static landscapes. Change will happen, sometimes slowly and sometimes suddenly. Where the vegetation remains unmanaged by any human intervention, changes accumulate gradually through the natural mortality of individual trees, or suddenly and catastrophically through the action of weather, fire, insect infestation, or rampant disease. In the absence of natural catastrophic disturbances, these forest tracts progress in succession toward a more shade-tolerant and longer lifespan species mix that tends to perpetuate itself.

Responsible stewardship dictates that all forests, including unharvested forest preserves, have a management plan with a detailed map. At a minimum, management plans for forest preserves include provisions for determining and permanently marking the preserve boundaries to protect the preserve from encroachment by human activities in adjacent parcels. If the property abuts a public road or contains hiking trails, provisions for hazard tree management should be included. The property map should indicate the location of other potential hazards (e.g., abandoned wells). A preserve management plan should also document tree growth rates and evidence of insect and disease damage. Documentation of forest health measures provides a benchmark for comparison in the event of future concerns or problems.

Forest preserve or unmanaged forest

Prioritizing the relative importance of natural features guides management decisions and the allocation of limited resources. This is especially crucial when there is a potential conflict between priorities (e.g., protection of a deer herd vs. maintenance of viable spring wildflower communities). The plan should also include strategies for monitoring and controlling invasive plant species, such as Japanese barberry, honeysuckle, and buckthorn (and many others!), that threaten the integrity of native tree, shrub, and wildflower populations.

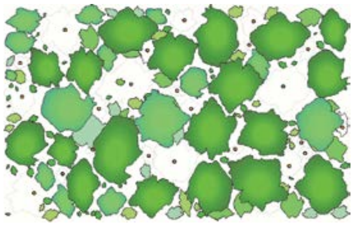
The defining feature of a preserve is the absence of deliberate manipulation of the vegetation. Thus, a preserve can be a young second-growth forest, a previously exploited mature forest, or a forest that has never been harvested. Young forest preserves will need to pass through the natural progression of stand development to achieve some of the advantages listed below.

Advantages

Easy to implement on private lands; maintains continuous forest cover; higher number of cavity and den trees in mature forests; favors shade-tolerant species (hemlock, beech, maple); increase in coarse woody debris (snags, dead logs); high watershed protection value.

Disadvantages

Limited or no income for landowner; change still occurs, unplanned and uncontrolled; more prone to some insect and disease infestations; lower diversity over time; shade-intolerant species will disappear without severe natural disturbance.



Single-tree selection

Single-Tree Selection

Single-tree selection (or, simply, the selection method) is used to create or maintain multiple-aged or uneven-aged conditions in a forest stand. Some trees from all size classes are harvested from the stand during each harvest entry or treatment. Selection systems result in the least dramatic changes in the forest compared with other techniques. A selection system is the most technically difficult to implement, but offers some unique advantages. This regeneration method most closely mimics the processes found in unmanaged forests, albeit at an accelerated pace, where trees gradually decline and die. Removals are done on a periodic basis so that trees of a variety of age classes are established and growing in the stand. The openings created for regeneration provide conditions most favorable to slower growing shade-tolerant species.

With this system it is difficult, if not impossible, to regenerate certain species in areas having high deer densities. Because the forest remains relatively open, deer can access the small patches of regeneration. In these patches, deer will preferentially browse some species (sugar maple, hemlock) and leave others. The end result is a silvicultural system that, by nature, restricts species diversity and simultaneously limits the abundance of palatable species. Few successes of the selection system exist in low-elevation northern hardwood stands. Low site quality further reduces species diversity by favoring typically less-desired species, including beech and striped maple.

Landowners who consciously practice uneven-aged management by the selection method are generally most interested in maintaining a continuous forest cover with trees of differing ages. The most desired growing stock can be identified and its growth enhanced through the gradual removal of poorer quality competing trees. Fast-growing trees and high-income yields are generally a lower priority for these landowners. This method is commonly applied in settings where multiple objectives, such as habitat, esthetics, recreation, and income, all must interact. **This method should not be confused with the commonly used and abused phrase "selective cutting," which has no basis in scientific forestry practice or terminology**. See "Diameter-Limit Cutting and High Grading" on page 40.

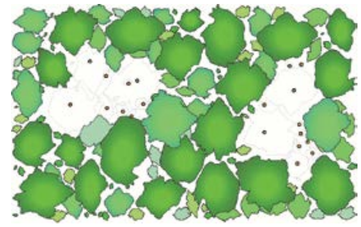
Advantages

Maintains continuous forest cover with low visual impact; periodic income for forest owner; favors shade-tolerant species; ability to remove declining trees; harvest schedules can be adjusted for market conditions; can maintain cavity and den trees.

Disadvantages

High skill required for successful implementation; higher costs for inventory, marking, and harvesting; may result in lower fiber productivity and lower yield in subsequent harvests; will lead to long-term loss of diversity; increased potential of damage to residual trees; may require several decades to transition an existing even-aged stand into an uneven-aged stand.

Group Selection or Patch Cutting



A variant of the traditional selection system is the group selection system, which removes small groups of trees rather than individual trees. The larger openings encourage regeneration by a greater diversity of species. Group selection compares with small-scale and localized high-intensity disturbance, such as multiple tree fall gaps associated with a microburst wind event, an ice storm, or, perhaps, pockets of insect or disease mortality. It is a hybrid method incorporating some of the features of both the single-tree selection and silvicultural clearcutting methods.

This approach does not select individual trees or distribute the intensity of the harvest evenly throughout the stand, but rather removes groups of trees. This method is suitable for certain habitat enhancement and can also be used to create a multiple-aged condition. Poorly formed and less valuable trees are cut and removed along with the commercially marketable ones.

Group selection or patch cutting

A greater diversity of regenerating species can result if the patches created are large enough to permit full sunlight to reach the forest floor in part of the patch, creating conditions in which shade-intolerant species can compete. A good rule of thumb for shade-intolerant species is to make the minimum opening twice as wide as the surrounding trees are tall, resulting in openings that are at least a half-acre in size. Smaller openings (¼ acre) may be sufficient for midtolerant species or to release saplings (e.g., white pine, sugar maple, red oak) established during previous harvests. During each harvest designed to create new groups, some tending or thinning of previously established groups should occur.

A forest managed using the group selection method will soon resemble a quilt of multiaged and multisized trees. Crucial to the long-term success of group selection is careful placement of the skid trails and roads. A well-designed road system not only lowers harvesting costs, but also provides the landowner with a trail system for recreational use.

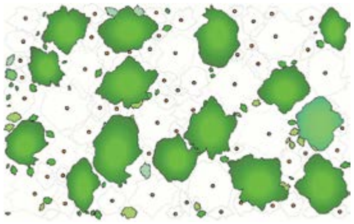
Advantages

Allows regeneration of shade-intolerant species without clearcutting if patches are large; provides the landowner with periodic income; provides a variety of habitats, from early to late successional; harvest schedules can be adjusted for market conditions.

Disadvantages

Resulting patchwork forest increases management costs; patches may be too small for midtolerant or intolerant species that require abundant sunlight; deer may concentrate feeding in recent patches; residual trees near patch edges may be susceptible to damage.

Shelterwood System



Shelterwood system

As its name implies, this method regenerates a new forest under the temporary shelter of older trees. The shelterwood system is similar to disturbances in which only a scattering of overstory trees remains alive. Examples of these disturbances include overgrazing by cattle, a moderate wildfire, or species-specific insect or disease mortality.

Residual trees should be selected from those that had been the most dominant stems in the preharvest forest in order to provide a seed source and moderate the climate for the new stand, which becomes established over a number of years and will become the next even-aged forest. Simultaneously, the residual overstory benefits from extra growth and increases in value until it, too, is removed. The landowner derives relatively substantial income from each of the harvests. A period with no timber income will follow the final overstory removal (see Silvicultural Clearcutting on page 38), however, until the new forest is old enough for commercial thinning.

The shelterwood regeneration method can be applied over two or three harvest stages, depending on physical, biological, and economic factors. This method dovetails well with recreational and habitat objectives. The initial harvests create an increasingly park-like tableau of majestic trees canopied over a carpet of new regeneration and wildflowers.

Landowners and foresters should pay attention to the presence of an established understory during the initial harvest. Forests that were thinned late in development may have an existing layer of unplanned-for small trees of less desired species and interfering vegetation in the understory. If present, these trees will begin to grow faster in response to the increase in light and soil moisture and will become the next forest. If the smaller trees are predominantly desired species, no understory treatment is needed. If the smaller trees are mostly undesirable species, some application of low disturbance is paramount. Low disturbance treatments might include fire, controlled grazing, or herbicides.

The overstory is harvested in two or three clearly defined stages scheduled several years apart. The number of overstory removal stages, and the interval between them, are scheduled according to the desired regeneration species mix. If, for example, a three-stage shelterwood system is applied in a stand at 10-year intervals, the overstory trees will be harvested over a 20-year timeframe and the new forest will be almost 20 years old by the time the final cut is made.

The goal of a shelterwood is to develop advanced regeneration of desired species. Advanced regeneration is older seedlings with large, well-established root systems that allow the seedlings to be competitive with other vegetation when the overstory is removed in the final harvest. New seedlings of many species, especially oaks, have poor height growth even in full sunlight until they have become advanced regeneration (Brose and others 2008).

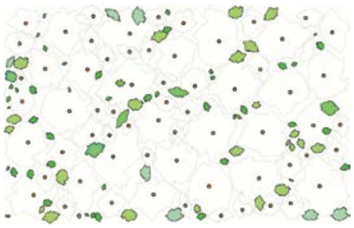
Advantages

Can increase midtolerant (e.g., oak) regeneration; increased volume growth of residual trees can maintain stand volume growth; least dramatic even-aged silvicultural system; possible genetic improvement in regeneration; damage to residual sawtimber usually minimal; increased vertical structure; regular periodic income to the landowner during harvest stages; some residual trees can be retained beyond the final harvest to maintain large and mature trees in the stand.

Disadvantages

High skill required for successful implementation; requires market for smaller trees; stands on thin or poorly drained soils may have significant loss of residual trees to windthrow; residual trees may lose quality due to epicormic branches (water sprouts); delay in implementing successive stages (harvests) can lead to loss of midtolerant species and damage to new regeneration.

White pine shelterwood



Silvicultural clearcutting

Silvicultural Clearcutting

It comes as a surprise to some that clearcutting, when properly planned and executed, is an indispensable and legitimate regeneration method. There are certain species of trees that fully develop only under the full sunlight conditions found after clearing all competing vegetation, including yellow-poplar, aspen, paper birch, many oaks, eastern redcedar, and butternut. Without clearcutting or final overstory removal following a shelterwood, these species will gradually decline and become rare.

There are other situations in which clearcutting is appropriate. Sometimes a forest stand is in such poor condition as a result of insect damage or past abuse that it does not fit with the long-range objectives of the landowner. Faced with this situation, a landowner may be better off to remove the existing stand and start over. There may also be times when a landowner wishes to convert an area from one type of species to another (e.g., diversify habitat by converting a stand of red maple to eastern white pine).

A clearcut mimics the conditions found following a catastrophic windstorm or fire, returning the forest to its earliest successional stage. It provides the best competitive advantage to the species that require full sunlight to survive. Regeneration must come from seedlings established prior to overstory removal, from a nearby seed source, or from root or stump sprouts. As with the other regeneration techniques, failure to ensure a source of seedlings will result in regeneration failure.

It is important to understand that for shade-intolerant regeneration to be successful, **complete removal of all competing vegetation is required**. Removing only the trees that are most valuable or larger than a certain size and leaving the others behind does not constitute a silviculturally correct clearcut system; it is a commercial clearcut with all of its potentially negative impacts. See "Diameter-Limit Cutting and High Grading" on page 40.

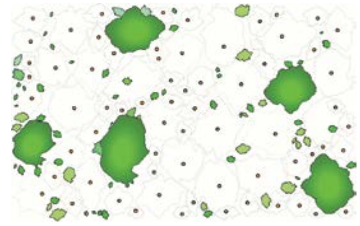
Advantages

Easiest method to mark and harvest; necessary to regenerate shade-intolerant species; high diversity of grasses and herbs until crown closure; provides early-succession habitat; potentially substantial one-time income for landowner.

Disadvantages

Esthetically less desirable for the general public; unacceptable for many small forest owners; residual poles and large saplings must be removed; no commercial timber income from forest for at least 30 to 40 years, more likely 60 to 75 years, depending on the species that is regenerated.

Reserve Tree



The reserve-tree method, a hybrid between a clearcut and a shelterwood system, is more esthetically pleasing in that not all of the overstory vegetation is removed. Borrowing an idea from the shelterwood system, a few trees are left scattered in the stand to provide vertical structure and a potential source of seed. The residual trees should be chosen from the healthiest trees in the stand, those likely to survive for another hundred years. The main difference between the reserve-tree method and a shelterwood system is that this method is a very high-intensity, but one-time (low frequency) disturbance event. All of the remaining vegetation is removed at once, and the new forest will be even aged. The reserve trees are kept to maintain some of the esthetic quality, provide some vertical structure heterogeneity, and potentially provide some seed. The reserve trees are generally kept until the next stand matures and is ready for its first commercial harvest. The new forest will be a mixture of species similar to that found in a silvicultural clearcut. Some habitat enhancement value from retaining these large scattered trees can be realized as well.

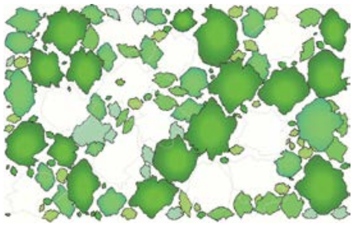
Reserve tree

Advantages

Esthetically more pleasing than a clearcut; provides regeneration conditions similar to a clearcut (i.e., beneficial for midtolerants and intolerants); reserve trees will be very large at end of next rotation; provides roost trees for raptors and other birds; reserve trees serve as a supplemental seed source, especially for pine and yellow-poplar.

Disadvantages

Reserve trees are susceptible to windthrow and lightning damage (and lost volume); crown breakage of reserve trees can damage smaller regeneration; large crowns of reserve trees may damage other trees during next harvest operation; no income for 30 to 40 years.



Diameter-limit cutting or high grading

Diameter-Limit Cutting and High Grading

A diameter-limit or high-grade cut is a high-impact cut in which only the most profitable trees are removed with little or no consideration for future conditions. All too often a high grade is disguised as a "selection" harvest. High-grade cutting, regardless of how "light" the cut is, has a negative long-term impact on both economic value and on forest health because no effort is made to ensure the establishment of desirable regeneration. Diameter-limit cutting may appear to be a sensitive method, cutting only the largest trees to supposedly release smaller, younger trees. In fact, smaller trees in the even-aged stands typical of the region are just slower growing trees of the same age as those targeted for removal. These activities are often termed "selective cutting" by individuals who are uninformed about or uninterested in proper silvicultural techniques.

Landowners may be mistakenly persuaded that the largest trees are overmature and should be harvested before they die. However, most large trees with deep, healthy crowns will not only survive for decades, but, if the stand is thinned, will grow faster and increase in multiple values. In even-aged stands, it is the poorly growing trees that should be removed until the stand can be properly regenerated.

Where economic necessity dictates a diameter-limit cut to generate sufficient income for a financial emergency (e.g., inheritance taxes, medical expenses, etc.), the negative impacts can be minimized. Ideally, spread the harvest over at least 3 years with an accelerated shelterwood system to minimize the shift towards a stand with many poorly formed and degraded residual trees. If cutting occurs all at once, cut or girdle all trees with poor form and low vigor. Trees with poor form will develop into wolf trees that inhibit the development of more valuable regeneration. They are also more susceptible to damage from wind, ice, and snowstorms. Trees with low vigor will continue to grow slowly and are susceptible to insect and disease infestation.

Advantages

None; high grading does not regenerate the stand. The landowner may have to wait decades or longer before another commercially viable harvest would be possible if all trees with diameters larger than 11 inches were harvested (a commercial clearcut). Typically, many of the smaller residual trees (5–10 inches in diameter) are slower growing, less valuable red maple, beech, and, in high elevations, fir.

Disadvantages

Immediate and long-term loss of fiber productivity and increased harvest intervals; increased proportion of cull and slow-growing trees in the stand; increased potential for damage to residual trees; loss of valuable midtolerant species (e.g., oaks); detrimental to wildlife species requiring early successional habitat.

Planting Seedlings

There are occasions when planting seedlings is the most efficient method of ensuring that the next forest contains a desired species. Eastern white pine is commonly planted in areas without mature pines to produce seed. Although tree planting is rewarding for the soul, it is truly backbreaking work. Inexperienced planters should count on planting no more than 100 seedlings per day. A carefully planned and tended plantation will bring years of satisfaction as the small seedlings quickly grow and form a new forest.

Keys to Success

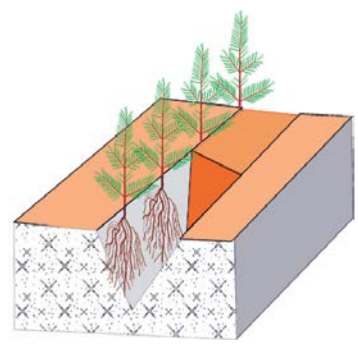
One of the keys to a successful plantation is matching the seedling species with existing site characteristics. If a particular species requires soil fertilization, then select a different species better suited for the site. Some species, such as white pine, can grow almost anywhere there is adequate sunlight. Other species, notably black walnut, will be difficult to grow in acidic soils with low fertility. Because of the burgeoning deer population, newly planted seedlings need protection from browse damage in much of the region.

Browse protection will be needed in areas with large deer herds.

Several studies have shown that the chance of success is increased if only the largest seedlings are planted. Plan on discarding the smallest 25 percent of the seedlings; they are often genetically inferior. The high cost of labor and browse protection does not justify planting seedlings that will not thrive. Seedlings are relatively inexpensive. Planting every seedling may save pennies now but will cost much more when those seedlings have to be replaced in several years.

Planting Tips

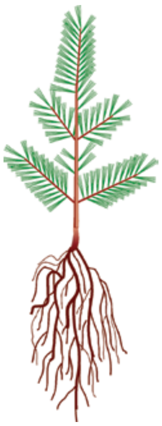
Immediately after accepting delivery of the bags or boxes of seedlings, store the containers in a shady location. Prolonged exposure of the shipping containers to direct sunlight may cause lethal heat buildup. If the seedlings cannot be planted within 1 week, "heel in" the seedlings in a V-shaped trench deep enough for the entire root system and lower part of the stem. Place seedlings side by side in a single layer on the side of the trench with the branches pointing up, and then cover the root systems completely. Pack soil around the roots and water them daily. Seedlings may be safely heeled in up to 2 weeks or more, if done properly.



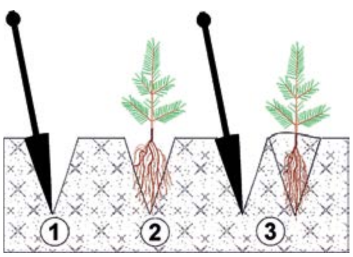
Seedlings that cannot be planted within 1 week should be "heeled in."

Keep the roots moist at all times prior to planting; exposing the root system to the drying effects of sunlight and wind for only a short time may be enough to kill the seedlings. Carry the seedlings to the planting site in a container that does not expose the roots to wind and sunlight.

Seedlings should be kept moist until they are placed in the planting hole. Grasses and other plants near seedlings should be removed.



A quality seedling should have a root system that is in balance with the top. Do not remove more than 50 percent of the root system if root pruning is required.



Follow these three steps when using a planting bar to ensure that the roots have good soil contact.

The planting hole should be opened before the seedlings are removed from the planting bucket. Seedlings with excessively long roots should be root pruned with a sharp knife or pruning shears prior to planting, but do not remove more than 50 percent of the root system.

A planting site 12 inches in diameter should be adequate for most seedlings. Scrape competing grass and weeds away from the planting site. Ideally, remove or control competing vegetation during the fall prior to planting. Planting seedlings with a planting bar includes three essential steps:

(1) Open a planting hole deep enough and wide enough for the roots.

(2) Place the seedling into the planting hole without twisting the roots. Twisting the roots to get the seedling into the planting hole can result in spiraling roots that can stagnate growth and eventually kill the tree.

(3) Close the planting hole and ensure the roots are tightly packed with soil to prevent them from drying out.

Section V: Species Regeneration Notes

This section outlines the general requirements for successfully regenerating select species and species groups (e.g., oak, maple). Included is background information on each species' or species group's history, distribution, and mature size, as well as its commercial, ecological, and esthetic values. The information on regenerating selected species is meant as a general guide and starting point for discussion with a professional forester. Specific guidelines will vary by species (i.e., northern red oak vs. scarlet oak), local soils, and other factors. The symbols used in this section are defined below.

Seed dispersal mechanisms: Tree species use a variety of mechanisms to disperse seed. Some species spread their seed upon the wind. Other species depend on small mammals to bury their seed, while birds carry some seeds great distances.


Small mammals


Birds


Wind

Reproductive modes: While all trees begin as seedlings, only the older, established seedlings (advanced regeneration) of some species can grow into canopy openings. Some species develop vigorous, fast-growing sprouts from buds hidden in stumps and roots.


Seedlings


Advanced regeneration


Stump sprout


Root suckering

Light requirements: The relative minimum requirement for sunlight varies among species. Tolerant species can survive and grow in full shade, midtolerant species in partial shade, and intolerant species only in full sunlight. Intolerant species require the full sunlight provided by clearcutting to develop into mature trees.


Tolerant

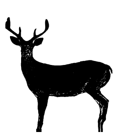

Midtolerant

Intolerant


Best with clearcutting

Site requirements: The definitions of site quality and topographic position are found on page 19.

Special considerations: Some problems might be encountered when regenerating specific species. For example, regenerating oaks will be difficult in areas with large deer herds. Species with thin bark are susceptible to damage by careless logging; wounding increases the possibility of rot.


Browsed by deer


Adapted to fire


Damaged by fire


Thin bark


Insect problems


Disease problems

White oak seedling

Oak (*Quercus* spp.)

Oak species, including northern red, black, scarlet, white, and chestnut, are widespread in forests throughout the Northeast. Oaks are disturbance-dependent species; most of our oak forests arose on lands that were burned or clearcut in the late 1800s to early 1900s. These large, majestic trees can live for several centuries, especially northern red and white oaks. Mature trees can reach over 120 feet tall with diameters of 2 feet or more. Northern red oak is one of the most valuable timber trees.

Uses

Wood Products

Veneer, fine furniture, cabinets, railroad ties, pallets, firewood, and flooring. White and chestnut oak are used to make barrels and ship hulls.

Veneer and fine furniture are just two of the many wood products made from northern red oak.

Wildlife

Many species feed on acorns, including white-tailed deer, turkeys, squirrels, chipmunks, and blue jays. White and chestnut oak acorns, because of their lower tannin content, are usually eaten before the acorns of other species.

Esthetics

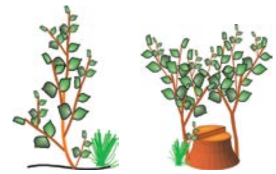
The massive trunks and wide-spreading branches typical of oaks lend the forest a gnarly, primeval sense of permanence. The leaves of scarlet and northern red oak often create a second peak in fall color during late October.

Regeneration

Seed Dispersal

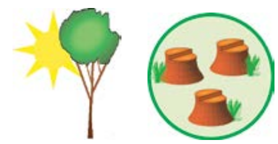

Oaks produce large seed crops at 2- to 10-year intervals. The large acorns that are dispersed by animals germinate in the spring.

Reproductive Modes



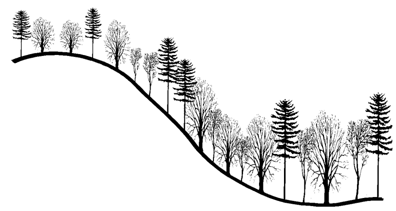
Successful oak reproduction develops from stump sprouting and advanced regeneration (older seedlings with large, well-established root systems). Mixing acorns into mineral soil during the initial shelterwood harvest increases acorn survival and germination success.

Light Requirements



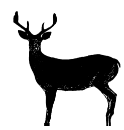
Although oak seedlings can grow in partial shade, overstory removal (final stage shelterwood, clearcutting, or patch cutting) is eventually required to achieve the full sunlight conditions necessary for seedlings to develop into mature trees.

Site Requirements



Northern red oak grows on good to average quality sites common to middle and lower slopes. Black and white oak grows on middle slopes with average site quality. Chestnut and scarlet oak grow on low-quality sites on upper slopes and ridgetops.

Special Considerations




Oaks need protection from browsing where deer herds are large. Where interfering plants are a problem, herbicides or prescribed burning can enhance seedling height growth and survival.

Best Methods to Successfully Regenerate Oak

Shelterwood system

Reserve tree

Red maple seedling

Maple (*Acer* spp.)

Red and sugar maple are found throughout the Northeast. Red maple has become the most common tree in many Northeastern States and accounts for one-fifth of all sawtimber trees. This increase has been attributed to fire suppression and the increased use of partial cutting (as opposed to the earlier practice of clearcutting). Their ability to grow in light (red maple) to heavy shade (sugar maple) allows both species to persist for decades as small saplings under the shade of larger trees. Sugar maple is a long-lived species that can survive for over 300 years; red maple commonly survives less than 150 years. Sugar maple is the larger of the two species, with mature trees commonly reaching over 100 feet tall with diameters of 2 feet or more.

Buckets are hung on sugar maple trees in the early spring to collect sap for maple syrup production.

Uses

Wood Products

Maple syrup, furniture, lumber, railroad ties, pallets, firewood, and specialty products.

Wildlife

The large hollows commonly found in centenarian maples are favorite den sites of raccoons, porcupines, and flying squirrels. Chickadees, wrens, and cardinals eat the seeds; deer eat the leaves and twigs.

Esthetics

The early kaleidoscope of fall colors in red maple swamps heralds the arrival of autumn. During early spring, red maple flowers mist the hills with a twinkling of reds and yellows. Sugar maple is the queen of the fall, with leaves turning every hue from clarion yellow through bright orange to beet red, often with the full range of colors on the same tree.

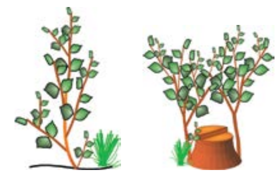
Regeneration

Seed Dispersal

Sugar maple produces large amounts of winged seeds (samara) at 3- to 7-year intervals; red maple does so about every other year. The seeds are primarily dispersed by the wind.

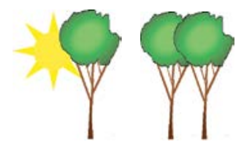
Reproductive Modes

Both species depend on advanced regeneration that develops after partial cutting or gaps created by the death of larger trees. Red maple reproduction can develop from stump sprouts.



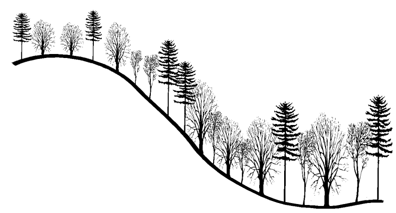
Light Requirements

Sugar maple is among the most shade-tolerant species in the Northeast, but also thrives in partial to full sun. Red maple is competitive in partial shade created by partial cutting.



Site Requirements

One of the reasons that the amount of red maple continues to increase is its ability to grow on all but the driest and wettest of sites. Sugar maple regeneration is found on lower slope positions where soil moisture is adequate. There is some evidence that its distribution is limited by the amount of calcium in the soil.



Special Considerations

Although logging damage rarely kills maples, it often creates wounds that cause extensive internal rot. Both species are weakened by wildfire and will be browsed by deer. Sugar maple is considered a valuable tree for timber and maple syrup production; red maple is used for maple syrup in some areas and may have valuable wood for lumber when it is free of defects.

Best Methods to Successfully Regenerate Maple

Single-tree selection

Group Selection


White pine seedling

Eastern White Pine (*Pinus strobus*)

Eastern white pine can grow on sites ranging from dry ridgetops to swampy valleys. In 1710, the British Parliament passed the White Pine Act to protect the large trees they needed for ship masts. Although largely ineffective, this was one of the first acts that set colonists and New England on a collision course with the British Empire.

This large, majestic species can live for 300 to 400 years or more. Mature trees can reach heights of 150 feet with diameters approaching 3 feet.

Uses

Wood Products
Furniture, lumber, bark mulch, and ship masts.

Wildlife
Red-breasted nuthatches eat pine seeds and nest in tree cavities. Red squirrels also eat pine seeds by methodically dismantling the cones.

Esthetics
Mature eastern white pine stands, with their massive boles soaring high above, inspire a sense of awe and reverence, especially when the wind whispers through the needles. The green of scattered pines accents fall colors and provides a reminder of life during the monochrome months of winter.


Mature eastern white pines inspire a sense of awe and reverence.

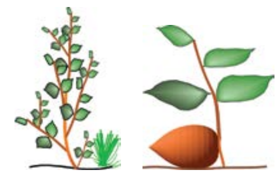
Regeneration

Seed Dispersal

Eastern white pine produces large amounts of seeds at 3- to 10-year intervals. The seeds are dispersed by the wind in the fall. Forgotten squirrel caches contribute to the dissemination of seeds and may be a partial explanation for white pine seedlings appearing in oak stands.

Reproductive Modes

Successful eastern white pine reproduction can be achieved from seedlings in large openings or clearcuts where a seed source is abundant and some mineral soil is exposed. Advanced regeneration is more important when using multiple-aged stand management. Where advanced regeneration is absent, regeneration success is increased by timing harvests to coincide with a heavy seed year. White pine cones take 2 years to mature; the presence of immature cones signals the potential of a subsequent seed year. Disturbing the forest floor to expose mineral soil also increases germination success.

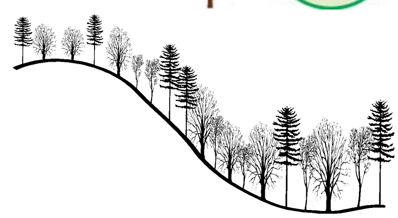


Light Requirements

Although eastern white pine seedlings can grow in partial shade, overstory removal (final stage shelterwood or clearcutting) is eventually necessary for seedlings to develop into mature trees.

Site Requirements

Eastern white pine can be found in every type of site, from deep sands to swamps. Regeneration success is best, however, on sites that are droughty for some period during the year.



Special Considerations

Eastern white pine seedlings need protection from wildfire and, occasionally, deer browsing. Ideally, regeneration should be established under a partial-shade overstory to reduce pine weevil damage.

Best Methods to Successfully Regenerate Eastern White Pine

Shelterwood system

Reserve tree


Birch seedling

Birch (*Betula* spp.)

Common birch species in the Northeast include paper, black, and yellow birch. Paper birch is a cold-climate species adapted to a variety of soils. Black birch, a warmer climate birch, is found on average sites. The range of yellow birch overlaps the two—it is found on moist to wet sites throughout its range. Black birch is now a common tree species as a result of its ability to reseed disturbed soils following partial cutting and resistance to deer browsing. Yellow and black birch contain oil of wintergreen (methyl salicylate), which gives birch beer its distinctive taste. The presence of this chemical, poisonous at high doses, provides some protection from deer browse damage.

In some stands, a high proportion of black birch trees may have one or more large cankers (*Nectria* spp.) that can reduce the potential economic value of this species. Although black and yellow birches can survive for 200 years, maximum ages of about 120 to 140 are more typical. Paper birch has a shorter lifespan and matures in 60 to 70 years. Mature trees are commonly 80 feet tall, with diameters less than 2 feet.


Yellow birch trees have characteristic peeling bark.

Uses

Wood Products
Veneer, lumber, railroad ties, pallets, pulp, and firewood. The economic value of these species varies throughout their range, depending on stem quality and market demand.

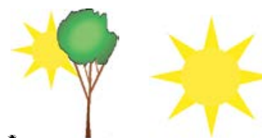
Wildlife
Birch seeds provide some winter food for chickadees, ruffed grouse, and chipmunks. Some birds use the bark of yellow birch for nesting material. Twigs and buds are browsed by deer, moose, and voles.

Esthetics
The golden fall foliage of birch leaves adds gaiety to autumn landscapes. The bright, white bark of paper birch is a North Country delight, and the frilly, peeling, light-colored bark of yellow birch is a unique feature of moist woodlands.

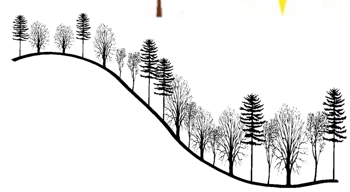
Regeneration

Seed Dispersal
Birches produce large amounts of seeds at 1- to 2-year intervals. The small seeds are dispersed 300 feet or more by the wind across crusted snow in midwinter. Seeds germinate best on exposed mineral soil. Yellow birch often germinates on logs that subsequently decay, leaving the tree on “stilted” roots.

Reproductive Modes
Successful birch reproduction can be achieved from seedlings in large openings or clearcuts. Black birch can also produce successful regeneration in openings created by shelterwood harvests.



Light Requirements
Although birch seedlings can grow in partial shade, overstory removal or death is necessary for seedlings to develop into mature trees.



Site Requirements
Black birch is commonly found on average quality sites; yellow birch grows on moister sites. Paper birch is adapted to a wide range of soils.

Special Considerations
Birches are susceptible to fire and logging damage. Although *Nectria* cankers are common on black birch and can make the wood unmerchantable, it rarely kills seedlings.

Best Methods to Successfully Regenerate Birch

Silvicultural clearcut (paper birch)

Group selection (black and yellow birch)

American beech seedling

American Beech (*Fagus grandifolia*)

Beech is a common species in forest preserves and high-graded stands. It is also a natural component of the northern hardwood forest type (i.e., beech-birch-maple) that is common throughout the region. This potentially slow-growing, long-lived species is our most shade-tolerant hardwood. Saplings can survive for 100 years or more in the understory before reaching the upper canopy. Unfortunately, an introduced insect-disease complex, beech bark disease, has killed and weakened beech across a large part of the Eastern United States. In the absence of beech bark disease, trees can survive for several centuries. Where beech bark disease is prevalent, it may be necessary to use herbicide to control beech root suckers and allow other species to establish.

A mature beech can approach 100 feet in height with diameters of 2 feet or more. Because beech has a tendency to root sucker, what appears to be a small beech grove is often an extended clone.

Uses

Wood Products
Furniture, chopping blocks, baskets, railroad ties, pallets, and firewood.

Wildlife
American beech seeds provide food for large mammals such as black bears and small mammals such as white-footed mice, as well as a variety of birds. American beech are prone to develop cavities.

Esthetics
The distinct smooth bark is an easy identifier for beech. Young lovers have been known to carve testimonials to their everlasting devotion in the bark of beech trees, though whether this contributes to the esthetics is questionable. Few herbaceous plants grow in the deep shade of a beech grove, leaving the forest, in the absence of beech sprouts, with an open, "shady glade" appearance.

The smooth bark of American beech is popular for carving.

Regeneration

Seed Dispersal

American beech produces large seed crops at 2- to 8-year intervals. The medium-sized seeds are dispersed by blue jays and small mammals.


Reproductive Modes

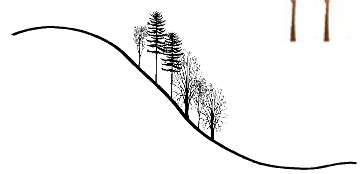
Successful American beech reproduction develops from root suckers and advanced regeneration. Beech seedlings can persist in the understory for decades. An abundance of beech suckers, called a beech thicket, produces an enduring shade that inhibits the regeneration of higher value hardwoods.


Light Requirements

American beech is among the most shade-tolerant hardwood species in the Northeast and can develop in all but the darkest shade.

Site Requirements

American beech regeneration is found on midslope positions where soil moisture is adequate. It is also found on lower slopes and benches.



Special Considerations

Logging damage can create wounds that cause extensive internal rot. Beech bark disease can stunt the growth of saplings and causes deformed growth. Beech is infrequently browsed by deer, except under unusual circumstances. Its foliage has little nutritional value.



Best Methods to Successfully Regenerate American Beech

Single-tree selection

Forest preserve

Red spruce seedlings

Spruce (*Picea* spp.)

Red, white, and black spruce are the common eastern spruces. Though all occur in the northern part of New York and New England, only red spruce, which is used for pulpwood and construction lumber, is commercially significant in this area. Red and white spruce grow on a variety of sites, but black spruce in this region is limited to wet, organic soils, often in kettlehole bogs left by the glaciers. Red spruce is a medium-sized, shade-tolerant tree that can live more than 400 years. It often grows in association with balsam fir.

Uses

Wood Products

Red spruce wood is light in color and weight and is straight grained. Knots are often small, tight, and red, making red spruce lumber valuable for construction. It is also used in papermaking. White spruce is planted for Christmas trees because it tolerates a range of growing conditions.

Esthetics

Along with balsam fir, spruce contributes to the “piney woods” ambiance appreciated by North Country visitors.

Spruce trees contribute to a “piney woods” ambiance.

Regeneration


Seed Dispersal

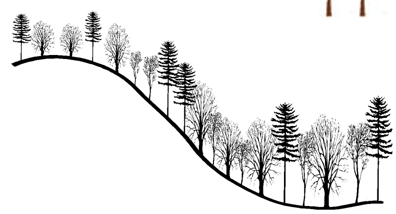
Good seed years occur every 3 to 8 years for red spruce. Seeds are dispersed by the wind, though squirrels may play a role in their dissemination. Germination is best on mineral soils and under cover.


Reproductive Modes

Selection systems, especially group selection, can result in adequate regeneration when groups are kept as small as ⅛ acre. Spruce is shallow rooted and prone to windthrow after logging, so removing more than one-fourth to one-half of the stocking is not recommended in partial harvests.

Light Requirements

Red spruce is tolerant to extremely tolerant. In early years especially, it grows slower than its common associates (balsam fir, and hardwood trees and shrubs). Release and thinning may be needed.



Site Requirements

Red spruce grows best in cool, moist climates and is found on shallow soils with a compact layer that holds water. It also grows on sites that are unfavorable to other species, such as on steep rocky slopes and wet bottomlands.


Special Considerations

Spruce forests provide wintering habitat for deer and other wildlife. Spruce budworm will damage red spruce, but causes more damage to balsam fir.

Best Methods to Successfully Regenerate Spruce

Single-tree selection

Shelterwood system

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Contact Information

For more information, contact the Stewardship Coordinator in your State.

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Department of Energy and
Environmental Protection
Division of Forestry
79 Elm Street
Hartford, CT 06106
Phone: 860-424-3630
Fax: 860-424-4070
www.ct.gov/deep/forestry

Maine
Department of Conservation
Maine Forest Service
22 State House Station
Augusta, ME 04333-0022
Phone: 207-287-2791
Fax: 207-287-8422
www.maine.gov/doc/mfs/

Massachusetts
Department of Conservation and Recreation
Division of State Parks and Recreation
251 Causeway Street, Suite 900
Boston, MA 02114-2104
Phone: 617-626-1250
Fax: 617-626-1449
www.mass.gov/dcr/stewardship/forestry/

New Hampshire
Department of Resources and
Economic Development
Division of Forests and Lands
P.O. Box 1856
Concord, NH 03302-1856
Phone: 603-271-2214
Fax: 603-271-6488
www.nhdfl.org/

New York
Department of Environmental Conservation
Division of Lands and Forests
625 Broadway
Albany, NY 12233-4250
Phone: 518-402-9405
Fax: 518-402-9208
www.dec.ny.gov/61.html

Rhode Island
Department of Environmental Management
Division of Forest Environment
1037 Hartford Pike
North Scituate, RI 02857
Phone: 401-647-3367
Fax: 401-647-3590
www.dem.ri.gov/programs/bnatres/forest/

Vermont
Department of Forests, Parks and Recreation
Division of Forestry
103 South Main Street – 10 South
Waterbury, VT 05671-0601
Phone: 802-241-3678
Fax: 802-244-1481
www.vtfpr.org

USDA Forest Service
Northeastern Area
State and Private Forestry
(serving the Northeastern States)
271 Mast Road
Durham, NH 03824
Phone: 603-868-7600
Fax: 603-868-7604
www.na.fs.fed.us/

Visit www.stateforesters.org/about/who-we-are for a list of forestry agencies in other States.

Additional Resources

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Internet Resources

Woodland Owners Guide to Internet Resources: States of the Northeast [http://na.fs.fed.us/pubs/misc/flg/]

Cornell University Cooperative Extension [www.ForestConnect.info]

Cornell University Cooperative Extension Forestry Social Media [http://CornellForestConnect.ning.com]

University of Connecticut Cooperative Extension [http://www.canr.uconn.edu/ces/forest/]

University of Maine Cooperative Extension [http://extension.umaine.edu/programs/natural-resources/]

University of Massachusetts Cooperative Extension [http://www.umassextension.org/]

University of New Hampshire Cooperative Extension [http://extension.unh.edu/Forestry/Forestry.htm]

University of Rhode Island Cooperative Extension [http://cels.uri.edu/ce/]

University of Vermont Extension [http://www.uvm.edu/extension/environment/]

USDA Forest Service, Northeastern Area State and Private Forestry [http://www.na.fs.fed.us/]

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