Forest Regeneration Handbook

A guide for forest owners, harvesting practitioners, and public officials

Editors:

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Introduction

Forests are dynamic. Seedlings germinate, grow, compete with each other and with larger trees. Some survive for hundreds of years. Change will happen. Which species will be predominant in 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.

This handbook was developed to provide an appreciation of how our forests developed and an understanding of forest regeneration concepts, including the importance of disturbance. This information will help landowners and public officials, in concert with professional foresters, make informed decisions about forest regeneration options tailored to their management objectives.

This handbook is divided into five sections.

• The first section provides a short history of the forest from the period of European colonization and large scale land clearing through 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.

• The second section explains basic concepts in forest regeneration. The importance of different combinations of light, moisture, and soil in determining success or failure of regeneration is discussed. It then details the adaptations of different species to distinct combinations of light, moisture, and soil conditions. The section concludes with an examination of competitive interference among trees striving to form part of the upper canopy.

• The third section examines the role of disturbance in maintaining habitat and species diversity. The influence distinct disturbance regimes have on forest composition is also explored.

• The fourth section introduces different methods (prescriptions) of forest management. The influence of each management style on the availability of light, moisture, and growing space for new regeneration is discussed. Because the primary reason for harvesting is often either income or a non-commodity amenity such as wildlife, the economic and esthetic considerations of each management method are also presented.

• The handbook concludes with a section detailing requirements to successfully regenerate specific species. As with the other sections, this section is not intended to be an authoritative reference, but rather to provide readers with sufficient information to make informed decisions about forest management options.

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Connecticut's Forest

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 walking along a trail and evidence of human impact on the land from earlier generations is discovered. Overgrown stone walls outline old pastures and grain fields. Occasionally, the outline of a charcoal mound or a sunken cellar of a farmhouse can be found. 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 Connecticut forest over the past 400 years with a special emphasis on disturbances and changes in land use patterns.

A Short Account of a Long History. When the Dutch and English began to settle in Connecticut around 1633, it is estimated that 90-95% of Connecticut was covered with forest. The colonists gradually cleared the land to plant their crops and orchards, create hayfields, and develop towns. In addition, they harvested the virgin forests to provide timber and firewood for domestic use and export. In 1710, the English Parliament passed the *White Pine Act* to protect the large white pines needed for masts for the royal fleet. It is interesting to note that an act about forest use was one of the first to contribute to the dispute between the colonists and the British Empire, that led to the American Revolution. It may be hard to believe, but by the mid-1800s, 75% of the state had either been converted to pasture or was plowed for food production.

The remaining quarter of the state that was forested was not like the forest we know. The forest 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, was used to make beds and chicken coops. An even larger part of the forest was cut for wood to cook meals and heat houses through the cold New England winters. Undoubtedly, many early Americans supplemented their diets with foods from the forest such as American chestnuts, maple syrup, blueberries, and game. These foods added variety to their diets and helped them survive the long New England winters.

In the mid-to-late 1800s, many farm families moved west to establish new farms on the more fertile soils, leading to the abandonment of many Connecticut farms. Other families moved to the mill towns to earn a higher income than could be gained on hardscrabble and overworked farmlands. The abandoned farms quickly converted to young forests of hardwood and pine.

The last great cut of our forests came in the late 1800s. Entire hillsides were cut to produce charcoal and fuelwood, not only for home use, but also for the local brick, brass, and iron industries. Stands were typically cut every 20-40 years when the trees were still small enough to be handled manually. Charcoal production fell dramatically in the early 1900s with the advent of cheap coal and petroleum. Most of the forest we see today has its origin in the charcoal-production era and consists of even-aged stands.

During the early 1900s, immense fires, covering up to 20,000 acres, regularly roared over the countryside. Some of these were accidental, caused by escaping sparks from railroads, homes, and industry. Records from the early 1900s indicate 15,000 to over 100,000 acres (in 1915) of forest fires in Connecticut. This wanton destruction of forest resources spurred the legislature to create the position of State Forest Fire Warden in 1905 to coordinate fighting of forest fires. The efforts of state and local fire fighters has reduced the annual amount of forest damaged by wildfires to an average of 1,300 acres in recent years.

Impacts to the forest have not been limited to clearing, cutting, and burning. Prior to the importation of the chestnut blight fungus, upwards of 25% of our forest was comprised of American chestnut trees. Gypsy moth outbreaks defoliated large swaths of the state between 1960-1990. Another species that has also been affected by insects and disease include eastern hemlock, currently threatened by the hemlock woolly adelgid.

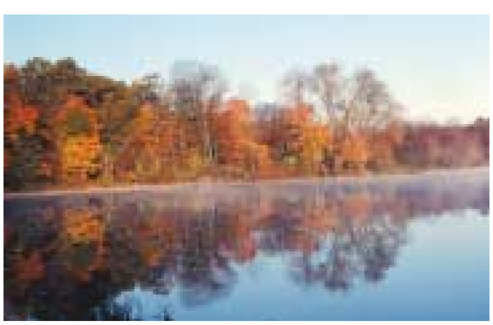
Historical records suggest that severe hurricanes strike Connecticut every 100-150 years. It was estimated that the 1938 hurricane destroyed over 100,000 public shade trees, every mature white pine stand east of the Connecticut River, and almost one-fifth of the timber in the state. Nearly 55,000 acres of forest were flattened and 45 miles inland near Putnam, salt damage was observed. Other weather events that have caused widespread forest destruction include ice storms (1898 and 1921), microbursts, and tornados such as the one that destroyed the Cathedral Pines in 1988.

Connecticut's Forest

The Forest Resource. A significant local forestry products industry has developed in the past several decades to utilize our maturing, but renewable, forest resource. Steve Broderick of the University of Connecticut Cooperative Extension System has reported that there are over 350 forest product firms in Connecticut employing approximately 3,600 people. These companies harvested an average of nearly 90 million board feet of timber annually between 1985 and 1998. Connecticut companies manufacture products ranging from fine furniture to shipping pallets, from cabinets to charcoal, and from doors to wood mulch. In addition, each year the Connecticut forest yields 15,000 gallons of maple syrup and almost all of the world's supply of witch hazel extract.

The value of the forest to Connecticut is much more than simply the timber and other forest products. First and foremost, forests protect watersheds, aquifers and groundwater supplies that provide the bulk of our clean drinking water. Trees can also provide air pollution control, acting as giant sponges to remove dust, particulates, and some airborne chemicals. In addition, trees cool our environment in the summer by recycling water and reflecting sunlight.

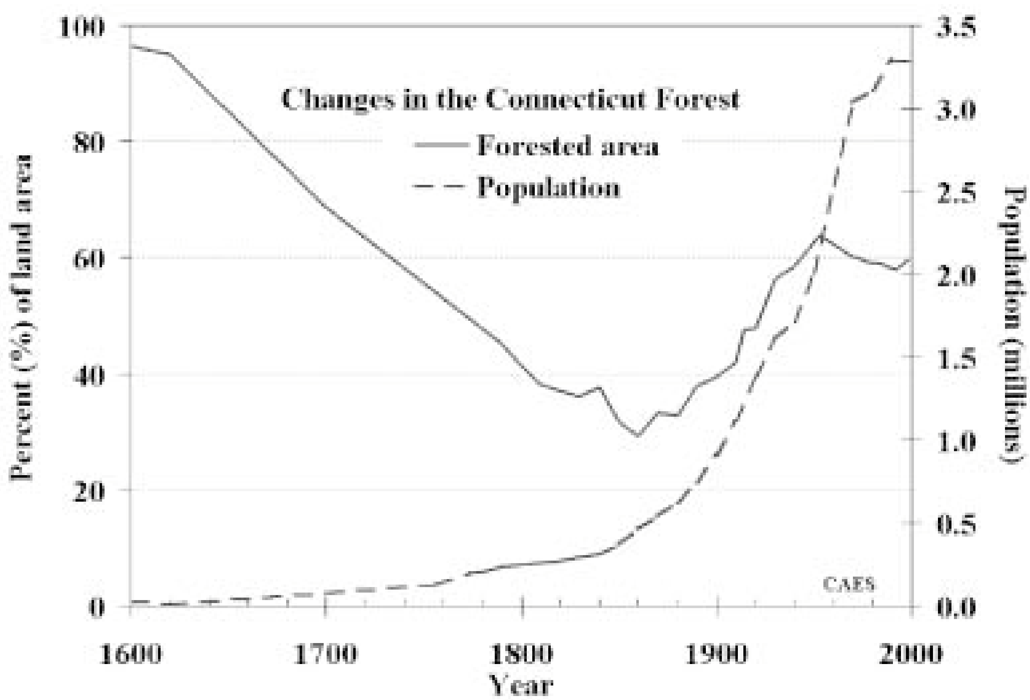
Forests contribute to the character of Connecticut and the $3.9 billion tourist industry. People come from all over the country, from all over the world, to view the kaleidoscope of fall colors that we sometimes take for granted. Healthy forests add to our enjoyment during other times of the year. We mark the end of winter 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 and yellow poplar tree trunks lend a sense of wilderness to modest urban parks.



The Changing Forest. The past 300 years has seen the 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 firewood and charcoal, from burned over stands to mature forests increasingly fragmented by encroaching suburban development.

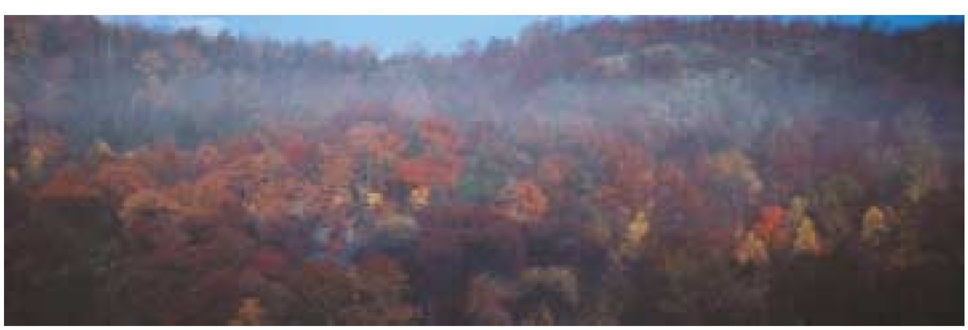
In Connecticut forests and in many northeastern and Appalachian forests, we are at the beginning of a second major successional change in forest composition in 100 years. Since the loss of American chestnut in the early 1900s, the Connecticut forest has been dominated by oak. A gradual conversion of our forest from oak to other species, such as maple, birch, and beech has taken place at a rate of approximately 5% every decade since 1938. Connecticut's oak forests could slowly disappear in the next 100 years if this trend continues.

As with the shift from chestnut to oak forests at the beginning of the century, the emergence of a forest dominated by northern hardwoods will alter the economic, ecological, and esthetic values of our forest. The consequences of these changes will last well into the 21st Century. Oak is more economically important than maple and



birch for its higher value, lower cull rates, and higher per acre volume growth. The shift from oak will also affect many wildlife and insect populations -- discriminating against those species dependent on oak and favoring those species associated with northern hardwoods.

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 always grew back. The same cannot be expected from the conversions made to other land uses today. As an ever-growing population demands an ever-increasing array of benefits from a continually shrinking forest land base, 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 benefits our forest resource provides.



Challenges Today and Tomorrow

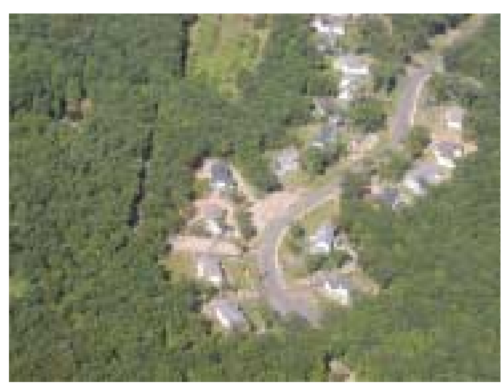
Whether landowner, professional forester, or concerned citizen, we must remain united in our commitment to sound forest management based on the best available science to avoid a return to the sad state of our forests during the mid-1800s. Five major challenges to forest management at the landscape level can be recognized in Connecticut. These are: invasive species, coping with deer, fragmentation and parcelization, maintaining habitat diversity, and the stewardship of private forestlands.

Alien (Non-native) Invasive Species. Alien invasives have interrupted natural plant associations and ecology since the time of European settlement. Settlers imported these species from their homelands for their one or two desirable characteristics. They were unaware of, or did not consider, their invasive potential.

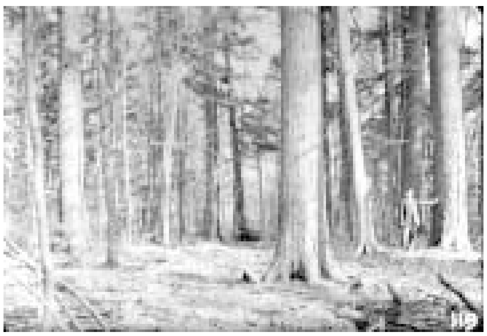
The introduction of alien plants has not only caused the displacement of native plants, but indirectly caused problems by bringing in alien fungi and insects.

Coping with Deer. White-tailed deer are very adaptable, and can survive in forest stands in all stages of development. The current high deer numbers have significantly altered the forest structure in Connecticut. Deer browsing affects regeneration, abundance and distribution of species. Forage is best from stands in early stages of succession, where the forest floor is open to sunlight.

Fragmentation and Parcelization. A major issue plaguing the forest resource of southern New England is population growth and the associated loss of forested open space to residential development. In a steadily suburbanizing region, privately-held land can be subject to change in ownership and use at any time. Change 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 and educational outreach, local planners and decision makers can obtain the data they need to make effective, high quality plans for conservation and development that will guide future growth in their towns.



In addition, by recognizing the importance of the upland forest resources 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 identifying areas most suitable for protection and sensitive areas that may be threatened by development.



Maintaining Habitat Diversity. The value of the early successional habitat found in seedling/sapling stands for a myriad of plant and animal species is not well appreciated. Unfortunately, Connecticut has been losing these valuable early successional habitats at an alarming rate attributable to three factors. 1) These habitats are ephemeral. The very nature of plant and tree growth causes them to change to more advanced successional stages. 2) Fewer farm fields are being abandoned and those that are abandoned are often converted to new development. 3) Partial cutting (uneven-aged) has become the dominant forest management practice. While it is unlikely that early successional habitat will completely disappear from Connecticut, it would be worthwhile to determine the critical minimum amount of early successional habitat required to maintain healthy populations of early successional species. Uneven-aged management often has significantly lower visual impact than even-aged management practices, but can accelerate the replacement of oak by birch, maple, and beech.

Private Lands Stewardship. The stewardship of forests on private lands needs to be a concern for landowners, local land-use officials and forest practitioners. Of the 60% of Connecticut that is forested, approximately 85% is in private 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 forestland ownership patterns and owner's goals are varied, diverse, and complex, there are some emergent trends and identifiable patterns, which may provide an indication about the long-range future of the forest resource.

Forestlands are becoming increasingly parcelized: Although the amount of forested 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" for all practical purposes. Over 75% of forested properties in Connecticut are parcels less than 10 acres in size.

Landowners are aging and lots of land will change hands in the next 15 years: The average age of forest landowners, for parcels greater than 10 acres, is somewhere in the early 60s. As current owners approach the end of their tenure, property is often sold off or transferred to other family members.

This process contributes significantly to parcelization, leading to fragmentation of resource.

Demand for benefits from the forest will increase: A steadily increasing population will demand an ever-increasing supply of products and other benefits from a steadily decreasing forest land base. Benefits derived from private forests that contribute to the economy and the overall quality of life in our society include the following broad categories:

Recreation – access, sites, facilities, and diverse opportunities

Habitat – private holdings provide the bulk of necessary habitat

Watershed protection – private forests protect most of the source-water areas for surface waters, groundwater and aquifer-recharge areas

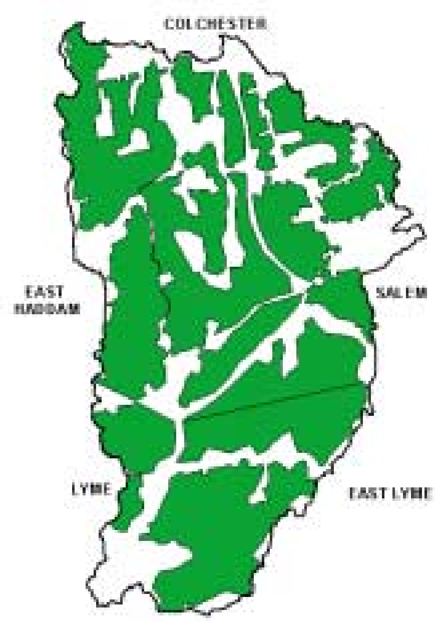
Forest Products – 75%+ of the raw material for a $700 million forest products industry comes from private forestlands

Aesthetics – the forest in Connecticut is considered to be the essential backdrop for the tourism industry

Landowners receive no benefit in return for many of the benefits they provide: The public enjoys many benefits derived from private forestlands that are public in nature, high quality water, cleaner air, wildlife habitat, and aesthetics, for example, and often take them for granted, at no cost. The people who own and manage the resource are not directly compensated for the public benefits to which their lands contribute.

Few, if any financial incentives exist for holding forestland, except forest products: Landowners often hold forest lands for reasons other than the promise of economic return, but often some economic return is necessary in order to keep the land "intact." Trees sold as raw material for forest products are often the only potential source of financial support for the land.

Managing the forest for periodic income from the sale of trees as raw material for forest products DEPENDS on being able to regenerate the forest successfully: When trees are harvested, the ability to replace them with a desirable mix of healthy and productive seedlings naturally 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 the knowledge of how to insure successful, desirable regeneration.



Limiting Factors

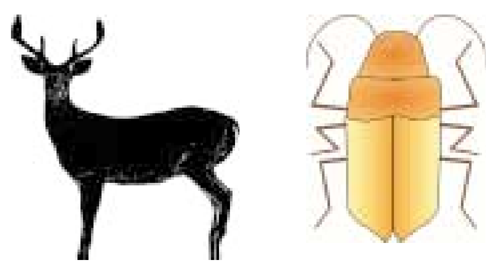
Trees and stands of trees are able to survive and grow under unique combinations of environmental conditions (e.g., nourishment, moisture, light and space). Different types of trees or stands require different combinations of these factors depending on their particular adaptations. Healthy, productive stands are those in which these factors are found in appropriate quantities for optimum growth and development for the species mix in question.

When one or more factors are in short supply the growth and development of the tree or stand is affected. Where a serious soil moisture shortage exists, for example, increasing the abundance of light, space or soil nutrients would not likely increase the growth rate of trees at that site. 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.

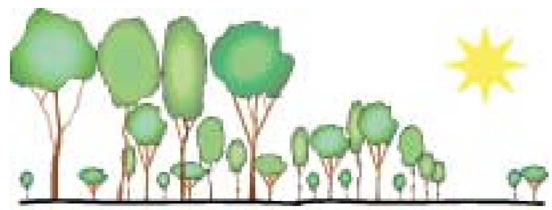
The manner in which these factors interact at the scale of the seedling will determine the ability of seedlings to germinate, become established, survive, and grow. Among the factors affecting growing conditions at any site, the one that, if increased, will result in the greatest corresponding increase in productivity of the stand, is considered to be the "most limiting factor".

ABIOTIC FACTORS

BIOTIC FACTORS

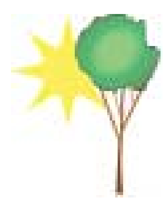
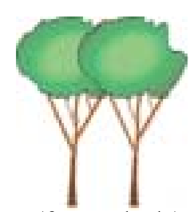


Light and Space. All growing plants require sunlight for photosynthesis…trees included! For most tree species in the Northeast, light availability is the most limiting factor to successful regeneration. Species that compete best in full sunlight have the capacity for rapid height growth and are often 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, and each canopy layer will intercept additional sunlight.



The minimum amount of light required for optimum growth and development (or even survival!) varies dramatically among tree species. The relative minimum requirement for sunlight is known as "shade tolerance". The shade tolerance of seedlings is a key limiting factor in their development. Disturbance in a stand will stimulate regeneration. When management objectives call for regenerating a mature forest, foresters plan harvesting systems to control the light availability, depending on the desired mix of seedling species.

SHADE TOLERANCE

Shade intolerant	Midtolerant	Shade tolerant
		
(Needs full sunlight)	(partial sunlight)	(forest shade)
Tulip-poplar	Red/black/scarlet oak	Hemlock
Paper/gray birch	Shagbark hickory	Sugar maple
Bitternut/mockernut/hickory	White/chestnut oak	Beech
Aspen	White pine	Basswood
Ash	Black/yellow birch	Stripe maple
Pin cherry	Pepperidge	Red maple

SPECIES CHARACTERISTICS ANALOGY

Shade intolerant	Midtolerant	Shade tolerant
High stakes gambler	*Investor*	*Miser*
Fast growth rate	Moderate growth	Slow growth rate
Few reserves	Some reserves	Large reserves
Short life span	Medium life span	Long life span
High mortality	Moderate mortality	Low mortality

Soil – "Back to Our Roots…" Taken together the root systems of trees in the forest comprise a complex interwoven carpet of live woody tissue in the upper layers of the soil that is dynamic, growing and ever changing. 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.

Ninety percent or more of tree roots are found in the top foot of soil because roots need oxygen to survive. Because most roots are near to the surface, they are susceptible to damage from heavy equipment, especially when soils are wet.

Soil Structure and Fertility. Soil characteristics are equally important to canopy disturbance in influencing forest composition in Connecticut. Not all soils are the same; in fact, it is amazing how many different soil types there are, each with its own peculiar characteristics. The mix of soil fertility, moisture, and texture determine whether a species will thrive on any given site.

A variety of soil nutrients must be present in available form for seedlings to be successful. Elements such as carbon, nitrogen and hydrogen 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.

Protecting Soil. Protecting the soil during any forest management practice is both the law and a moral obligation. Every forest management activity from trail construction, to firewood cutting, to regeneration harvests in mature forests must be conducted in a manner that does not result in excessive detrimental disturbances to the forest soil. Limiting sedimentation of eroded soil in streams is a primary concern of foresters.

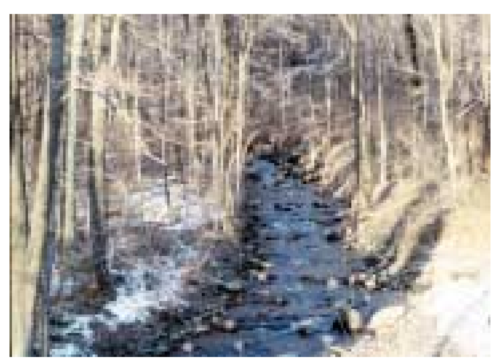
Properly conducted harvesting operations will not only control the amount of sunlight reaching the forest floor, but leave the stand with soil conditions that are ideal for promoting successful regeneration.

Soil Moisture. Forests have a remarkable capacity to absorb stormwater, regulate stream flow, and clean water as it moves through the forest ecosystem. Compared to other land uses, forests are excellent land cover for protecting water quality. The interactions between the forest soil, moisture, and seedlings when forest stands are harvested and regenerated can best be understood by examining how forests and water interact in undisturbed environments.

When precipitation (rain and snow) falls on an undisturbed forest, much of it never reaches streams and underground aquifers. Some is caught on the leaves and branches and evaporated back into the air. Some of the rain 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. Evapotranspiration can account for one-third or more of the annual precipitation.

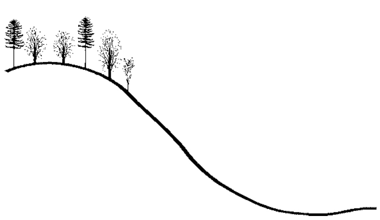
The undisturbed forest floor consists of a thick layer of leaf litter on top of a loose friable soil that is high in organic matter and securely bound by tree roots. It has a tremendous capacity to absorb rainfall. Overland flow or runoff is a rare event in the forest, and significant erosion is virtually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

Species/Moisture Relationships. Each species has adaptations for distinct moisture regimes. Some species have adaptations for extended periods of drought (e.g., pitch pine, chestnut oak). Other species are adapted for extended flooding (e.g. silver maple, pin oak). Saturated soils and surface water present unique challenges for trees because roots need to breathe. Most species grow in the continuum between very dry and very wet soils. Our most valuable timber species tend to 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.

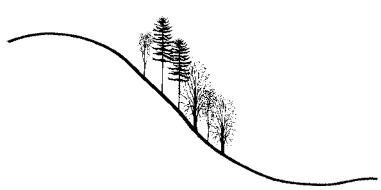


Site Quality – Putting it All Together. The natural vegetative cover for most of Southern New England is forest of one type or another, and while this may generally be the case, it is certainly true that some sites are better for growing forest trees than others. Tree growth is a function of the particular capabilities of the species, primarily genetic, interacting with the environment where the tree is located. The environmental factors associated with the moisture, soil fertility, and drainage described earlier are collectively known as *Site Quality*. Obviously, perhaps, a site that has favorable conditions for tree growth is considered "good", while a site with conditions that inhibit growth would be considered "poor".

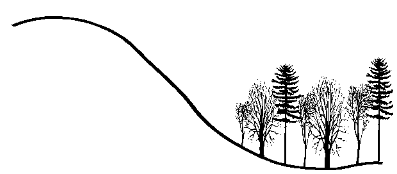
Less obvious, perhaps, is the fact that environmental conditions considered favorable for one species may be unfavorable for another, so any discussion of site quality must be made in the context of a particular species or species mix (forest type). In Connecticut, trees grow almost everywhere except on solid rock and in areas of permanent standing water.



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

Competition Overview. New seedlings for most species in Southern New England originate naturally from one of two sources: germinating seeds or sprouts from stumps or roots. Successful natural regeneration depends upon the availability of a nearby seed source for the desired species and/or a sufficient number of sprouts from stumps or roots. As a rule of thumb, the older trees are when harvested, the less their ability to produce root or stump sprouts. So following harvesting in mature stands, regeneration of desired species is not likely to occur without a reliable source of seeds nearby. It is very important to remember that when the overstory of a stand is only partially removed, the species that comprise the residual stand will also be the predominant seed source for the new forest that will grow to replace the old.

Once established, seedlings must compete for light, moisture, nutrients, and space, not only with other tree seedlings, but also with shrubs, grasses, and herbaceous plants. Only rarely do certain species, such as American beech and eastern hemlock, have the natural ability to germinate, survive and compete in heavy shade. Many species require abundant light in order to survive and grow.

Biotic Competition – Diseases. Diseases have historically played an important role in forest health and will continue to impact forest regeneration. Because forest diseases, in general, cannot be easily controlled, their impact is to limit the choice of species that may be successfully regenerated.

Biotic Competition – Insects. As with forest diseases, insect pests often limit species choices when regenerating forests. The natural defense mechanisms of seedlings decline when they become stressed and weakened due to factors such as the change in microsite conditions (light, moisture, etc). Stressed trees are more susceptible to insect pests.

See descriptions of diseases and insects in the web version

Control of Competing Vegetation. A good vegetable gardener would never expect to grow tomatoes without ever pulling weeds, and managing a forest for successful regeneration can be viewed in much the same way. Removing the competing vegetation is like pulling the weeds to help the desired plant or tree grow.

When planning a harvest of overstory trees it is important to consider reducing competition from undesirable understory vegetation if the desired regeneration is to be successful. This might involve extra time and expense, but this step is essential to insure the success of desired regeneration.

Stand Development–Regeneration Bottlenecks. Conditions change rapidly within a forest stand during early stand development, and the success or failure of a new stand of desirable regeneration rests on its ability to overcome certain barriers, or "bottlenecks". Regeneration bottlenecks can be categorized according to the period of early stand development during which they may have the most influence on the desired regeneration species.

Unmanaged forests in Connecticut typically have 5,000 to 12,000 seedlings and saplings per acre. Regeneration densities can soar upwards beyond 30,000 stems/acre several years after harvesting. These estimates do not include untold numbers of shrubs, ferns, grasses, and herbaceous plants. At the beginning of canopy closure, when crown classes can be distinguished, fewer than 2000 stems/acre remain in the upper canopy.

Stand Initiation. It is important to realize that only regeneration that is established by the end of the first growing season after a disturbance (such as harvest) has any chance of forming a part of the future forest.

The timing of a harvest, the provision for a reliable and desirable source of seeds or sprouts, and the preparation of a suitable seedbed are factors that must be incorporated into a management system to successfully obtain regeneration consistent with the landowner's objectives.

Establishment. During the 3 to 4 years following that critical first growing season, trees in the young stand must compete with each other and other vegetation for sunlight, moisture, and nutrients in the upper layers of the soil. Regeneration density may peak during this period at 30,000 stems/acre or more.

Seedlings undergo dramatic root and branch development. Competition during this stage is often a race to physically occupy horizontal and vertical growing space, rather than direct competition. Micro-site 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.

Free to Grow Status/Vertical Stratification. 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 around them to grow and develop competitive branch and root systems.

Disturbance–The Agent of Change

Since the receding of the last Ice Age in North America 10-12,000 years ago, natural and man-made disturbances, such as windstorms, floods, fire and clearing, have played a critical role in the establishment, growth, death and re-establishment of forests. Forests are not a diorama. Trees grow, reproduce, and eventually die. Catastrophic disturbances have created the conditions necessary to perpetuate pioneer species and early successional habitats. Minor disturbances have permitted 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-tree mortality, species able to establish and grow in forest shade such as maple, beech, and hemlock are favored. Oak seedlings need higher levels of light to develop into saplings than commonly found in forest preserve and/or partially cut stands. Thus, managing a forest as a preserve is an active decision for a gradual conversion to a forest with more beech and maple. Without proactive forest management, (or a large hurricane!) oaks will gradually disappear from many of our forests.

Changes in forest composition have been caused by changes in the type and intensity of forest disturbance. Harvesting trees for forest products constitutes disturbance in the forest of an artificial or man-made nature, and because tree species have adapted to regenerate successfully under certain disturbance regimes, harvesting methods are often designed to mimic certain natural disturbances.

There is, however, one very important distinction between a natural disturbance and a timber harvest. When a harvest is planned, *the person who chooses the trees to be harvested 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 productivity of the forest that the person making these decisions be knowledgeable about species' requirements.

Sound forest stewardship is a true intergenerational commitment. Decisions made today by landowners, public officials, and foresters will affect the composition and habitat diversity of forests that will be enjoyed by generations yet unborn.

Mimicking Natural Disturbance. As every 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 traprock ridges, because they have 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.

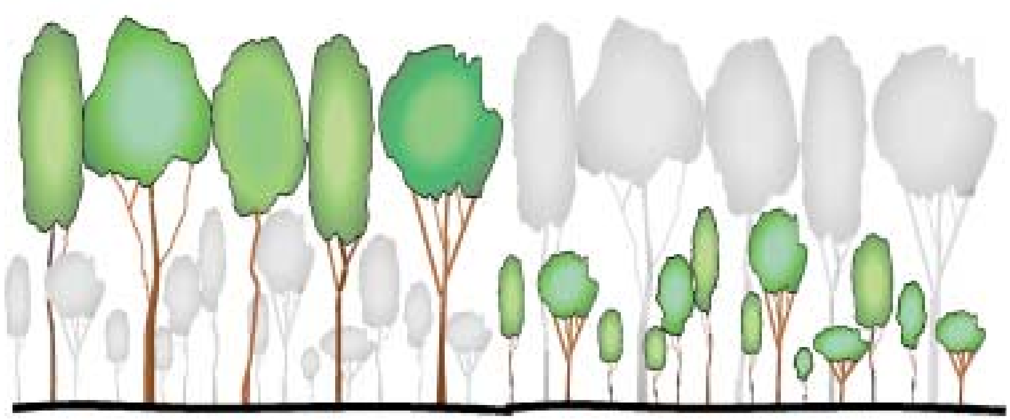
Less well appreciated and understood are the adaptations forest trees have to different disturbance regimes. Disturbance regimes are determined by the relative combination of three components: type, intensity, and frequency. These components are explained in more detail on the following pages.

Properly conducted, most harvesting methods mimic a natural disturbance. Ideally, the forester will first ascertain the long term management goals of the landowner and then prepare a management prescription to achieve those goals. An integral part of the management plan is to determine a species mix to best achieve those goals. Because each species is best adapted to a specific disturbance regime, the management prescription should incorporate harvesting methods that closely mimic optimum disturbance regimes for each species. If the desired species possess strategies for more than one disturbance regime (e.g., American beech and northern red oak), the forester can suggest several alternative management presecriptions to the landowner.

Disturbance Type. The *type* of disturbance occurring in a forest stand has a direct effect on the successful survival of regeneration. Disturbance types may vary from those that remove only the smallest trees in the understory (low disturbance), such as in a stand where grazing is permitted, to those which predominantly remove the largest trees in the stand, such as a severe wind storm (high disturbance).

A high, or overstory disturbance, will dramatically increase the amount of direct sunlight that reaches the forest floor and will often increase mineral soil exposure as many trees are uprooted. Increased sunlight also increases soil temperatures. Large trees can transpire up to an inch of water per week, thus soil moisture increases temporarily when they are removed by harvesting or destroyed by a windstorm.

A low, or understory disturbance, will also increase the amount of sunlight (ambient or filtered) available to seedlings by removing the shade cast by saplings and small trees. In contrast with high disturbance, low disturbance has minimal impact on soil moisture, temperature, and exposure.



LOW (UNDERSTORY) DISTURBANCE

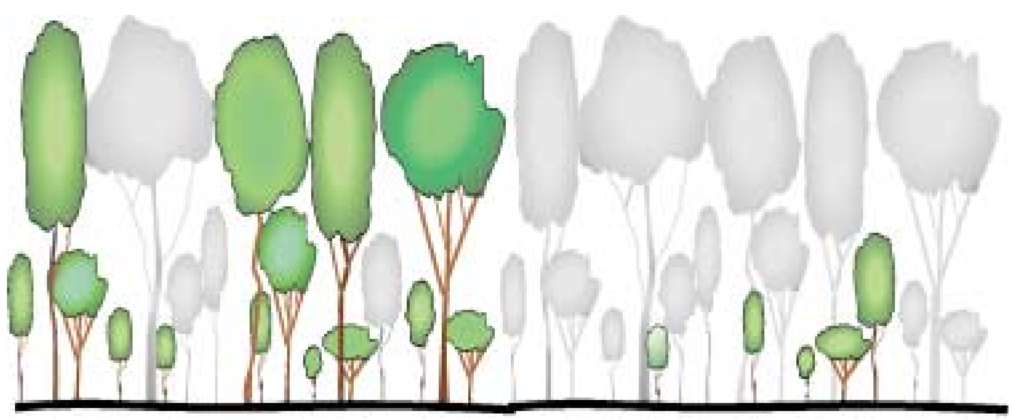
HIGH (OVERSTORY) DISTURBANCE

Disturbance Intensity. Disturbance *intensity* affects the success of regeneration through its influence on limiting factors. Within a given stand, whether windthrow or mortality results in the loss of a single tree, or a large group of trees, seedlings will become established and grow in those openings. The species that survive and continue to grow will vary depending on the intensity of the disturbance.

Slow, gradual mortality of individual trees favors shade tolerant species (sugar maple, beech) that can germinate and become established in the duff, or undisturbed leaf litter of the forest floor, and compete in the presence of a mature overstory.

A storm microburst that uproots a small group of trees gives the advantage to species (black birch, red maple) that can become established in partial to full sunlight and may be more competitive where some bare mineral soil is exposed.

An intense disturbance, such as a crown fire or clearcut, will favor species (aspen, pitch pine) that are adapted to full sunlight for best development. These species are unlikely to be able to compete unless an intense disturbance removes both overstory and understory trees.



SINGLE TREE DISTURBANCE

STAND REPLACEMENT DISTURBANCE

Disturbance Frequency. The *frequency* of forest disturbance can vary from yearly (single tree mortality), to decades (drought), to once a century (hurricanes). Indeed, many of the stands in state forests are currently managed on 100-200 year intervals between regenerations. This is similar to the return cycle for major hurricanes in southern New England.

In contrast, forests in Connecticut burned an average of once every 7 years before the 1920s. Before modern forestry practices became widespread in the early 1900s, many stands were cut every 30-60 years for firewood and charcoal production. Frequent cuttings in younger stands of dense saplings and poles for fuelwood or biomass certainly favors those species that can regenerate rapidly from root or stump sprouts such as oak and some shrub species (blueberry).

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

Stands in which disturbances do not occur over long periods of time ultimately tend to be comprised of mostly shade-tolerant, slow-growing species with long life spans. 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.

Forest Management

Forest regeneration methods are based on three premises: 1. Natural disturbances vary in type, intensity, frequency, and scale. 2. Each species is adapted to, and will regenerate successfully under conditions created by specific disturbance regimes. 3. Harvesting for forest products is a disturbance.

Therefore, it stands to reason that for a harvesting method to result in successful regeneration of a desirable species or mix it should most closely mimic the natural disturbance regime for which the desired species is adapted. 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.

In light of the long-range management goals and objectives for a forested parcel, as identified by the owner, when planning to harvest forest products a forester should recommend and implement a harvesting method that is most similar to the natural disturbance regimes for which the desired regeneration species are most closely adapted.

On the following pages, you will find descriptions of different silvicultural systems, or harvesting and regeneration methods, that are commonly prescribed in Southern New England. They are compared to the natural disturbance regimes they mimic, and a comparative listing of management objective considerations is provided. This listing can be viewed as pro/con or advantage/disadvantage, but that judgment must be made within the context of clearly stated management objectives.

Examples of management objectives for any piece of forestland could include such things as: Maximize habitat value for game bird; Increase recreational value; Preserve privacy and aesthetic values; and Maximize periodic income from forest products

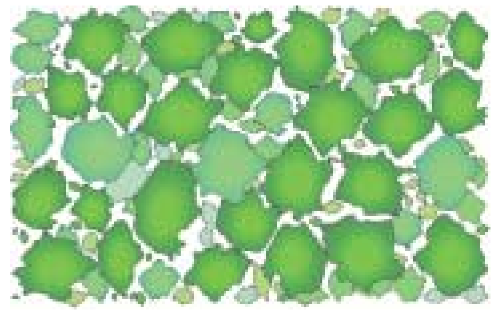
It is readily apparent even from this partial list that two or more of these objectives can be achieved with an appropriate management prescription. It should also be recognized that some of these objectives might not be compatible with each other within the same stand of trees or even on the same forested tract. So before deciding the pro or con of the consequences of any particular harvesting method, the management objectives and priorities for a stand must be clearly stated.

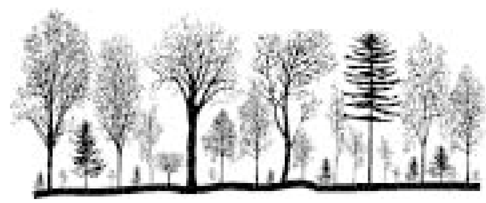
UNEVEN-AGED (e.g. forest preserve, diameter limit, single-tree selection)	Trees	Sugar maple, American beech, black and yellow birch, eastern hemlock, basswood, pignut hickory
	Shrubs	Flowering dogwood, mountain laurel, hobblebush, striped maple, witchhazel, ferns
	Wildlife	Pileated woodpecker, flying squirrels, Acadian flycatcher, Cerulean warbler, Scarlet tananger
EVEN-AGED (e.g., shelterwood, clearcut, coppice with standards)	Trees	Oak, eastern white pine, black cherry, paper birch, white ash, tulip-poplar, aspen, eastern red cedar
	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, eastern cottontail

Forest Preserve/Unmanaged Forest. Forest preserves are not dioramas. Change happens. Where the vegetation remains unmanaged by any human intervention, slow 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-life-span species mix that tends to perpetuate itself.

Responsible stewardship requires 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 prevent damage to the preserve by accidental encroachment of human activities in adjacent parcels. Where the property abuts a public road, or if hiking trails are present, provisions for hazard tree management should be included. The property map should indicate the location of other potential hazards (e.g., abandoned wells).

Prioritizing the relative importance of natural features will facilitate objective management decisions and allocation of limited resources. This is especially crucial when there is a potential conflict between priorities (protection of deer herd vs. maintenance of viable wildflower communities). The plan should also include strategies for monitoring and controlling invasive alien species, such as barberry and Norway maple, that could threaten the integrity of native populations.





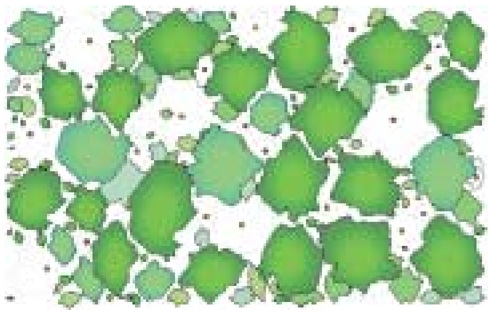
Unmanaged forest

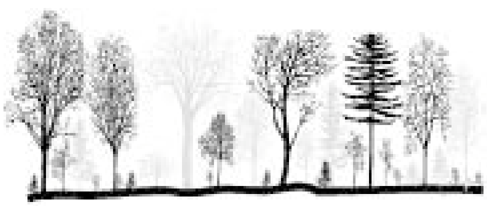
Advantages

Easy to implement; Maintains continuous forest cover; Higher number of cavity and den trees; Favors shade tolerant species (hemlock, beech, maple); Increase in coarse woody debris (snags, dead logs); High watershed protection value

Disadvantages

No income for landowner; Change happens, 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 by foresters to create or maintain multiple aged or uneven age conditions in a forest stand. Individual trees that are mature or declining in health are harvested from the stand in a manner that minimizes disturbance to the residual stand. This regeneration method most closely mimics the processes found in unmanaged forests, albeit at an accelerated pace, where trees die and drop out of the stand gradually. 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, however, tend to provide conditions most favorable for slower-growing shade tolerant species.

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. High-value growing stock can be identified and their growth enhanced through the gradual removal of poorer 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, aesthetics, 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/High grading."*

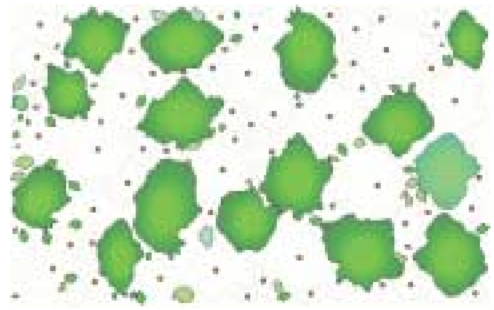
Advantages

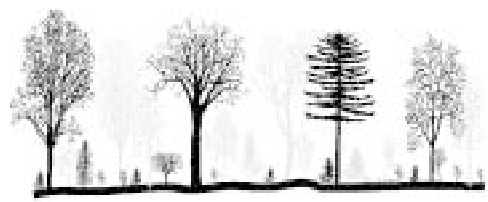
Maintains continuous forest cover with low visual impact; Periodic income for forest owner, albeit low; Favors shade tolerant species (where desired); Ability to remove declining trees; Harvest schedules can be adjusted for market conditions

Disadvantages

High skill required for successful implementation; Higher costs for inventory, marking, and harvesting; May result in lower fiber productivity/yield in subsequent harvests; Will lead to long-term loss of diversity; Increased potential of damage to residual trees

Shelterwood. As its name implies, this method regenerates a new forest under the shelter of older trees. Mimicking disturbances in which only the healthiest dominant trees survive, the best growing, most desirable trees in the stand are left during the initial harvests. The residual overstory provides the seed source and cover for the regenerating forest, which becomes established over a number of years and will essentially be another even-aged forest. Simultaneously extra growth will be gained on the best stems, increasing stand value. The landowner would derive relatively substantial income from each of the harvests. However, following the final overstory removal a period of no income will occur until the new forest is old enough for commercial thinning.





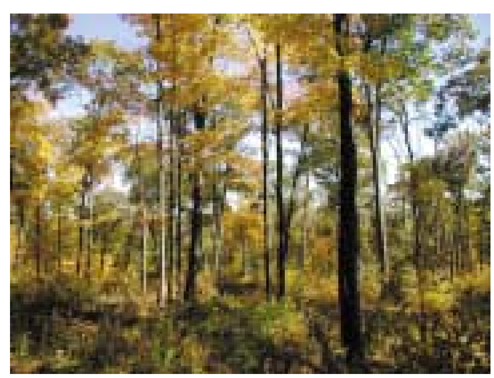
Shelterwood

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

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 15-year intervals, then the overstory trees will be harvested over a 30-year time frame, and the new forest will be almost 30 years old by the time the final cut is made.

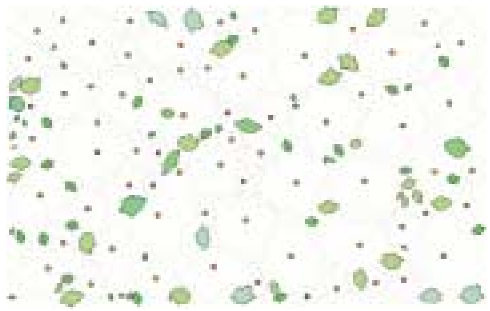
Advantages

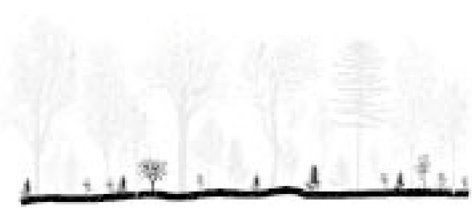
Can increase midtolerant (e.g., oak) regeneration; Increased volume growth of residual trees can maintain stand volume growth; Possible genetic improvement in regeneration; Damage to residual sawtimber usually minimal; Increased vertical structure heterogeneity; Regular periodic income to the landowner during harvest stages



Disadvantages

High skill required for successful implementation; Requires market for smaller trees; Residual volume may be lost to storm damage or epicormic branches (water sprouts); Delay in removing residual trees can lead to loss of midtolerant species and damage to new regeneration





Silvicultural clearcut

Silvicultural Clearcutting. It comes as a surprise to some people that clearcutting, when properly planned and executed, is a legitimate and indispensable regeneration method. There are certain species of trees that fully develop only under the full sunlight conditions found after clearing all competing vegetation. This group of species includes tulip poplar, aspen, paper birch, most oaks, eastern red cedar, butternut, and others. Without clearcutting or final overstory removal during a shelterwood these species will gradually decline and become rare in most of our forests.

There are other situations when clearcutting is appropriate. Sometimes a forest stand is in such terrible condition as a result of insect damage or other 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., diversifying habitat by converting a stand of red maple to eastern white pine).

Regardless of the reason, a clearcut, while perhaps producing a one-time substantial income for the landowner, sets the forest back to its earliest successional stage. A clearcut mimics the conditions found following a catastrophic windstorm or fire and provides the best competitive advantage to the species that require full sunlight to survive. Regeneration must come as seedlings from a seed source nearby or from root or stump sprouts. It is important to understand that for regeneration to be successful *complete removal of all competing vegetation is required.* Just removing trees that are most valuable or larger than a certain size and leaving the others behind does not constitute a silviculturally correct clearcut system. Rather, this is a commercial clearcut with all of its potentially negative impacts. *See: "Diameter Limit/High Grading."*

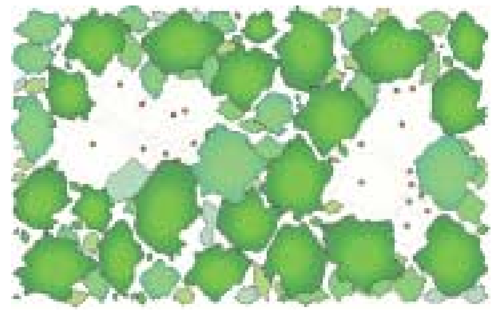
Advantages

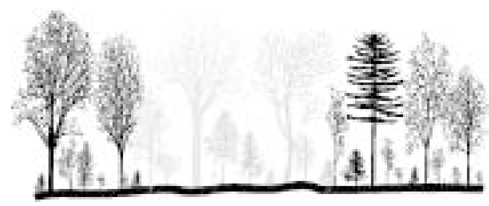
Easiest method to mark and harvest; Necessary to regenerate shade intolerant species; High diversity of grasses and herbs until crown closure; Provides early succession habitat; Potentially substantial one-time income for landowner

Disadvantages

Aesthetically less desirable for general public; Unacceptable for many small forest owners; It costs money to remove residual poles and large saplings; No income from forest for at least 30-40 years; Susceptible to soil erosion if poorly implemented

Group Selection/ Patch Cutting. Group selection is a hybrid incorporating some of features of both the 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 within pre-defined areas scattered through the stand. It leaves undisturbed forest in between, much like the conditions one would find following a severe "microburst" wind event. This method is very suitable for certain habitat enhancement, and can also be used to create a multiple aged condition within a forested parcel. Note that proper management dictates that poorly formed and less valuable trees be cut or removed along with the commercially marketable ones.





Group selection

A greater diversity of regeneration species can result if the patches created are large enough to permit full sunlight to reach the forest floor in part of the patch, so as to create 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. This will result in openings that are at least half an acre in size. Smaller openings (1/4 acre) may be sufficient for midtolerant species or to release white pine saplings.

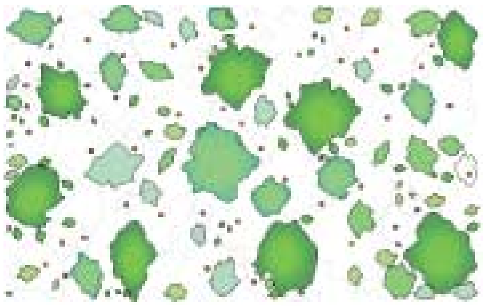
A forest managed using the group selection method will soon resemble a quilt of multi-aged and multi-sized trees. Crucial to the long-term success of group selection is careful placement of the skid trails and roads. A well-designed road system will not only lower harvesting costs, but provides the landowner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

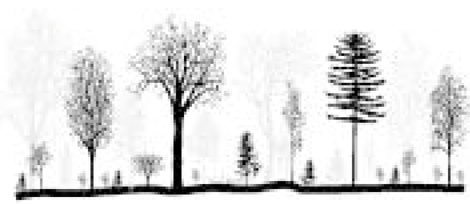
Advantages

Allows regeneration of shade intolerant species without clearcutting; Provides 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/intolerant species; Deer may concentrate feeding in recent patches; Residual trees near patch edges may be susceptible to damage





Coppice with standards

Coppice with Standards. The coppice with standards method, originally developed in Europe to provide fuel and wattle for tenant farmers and timber for estate owners, may be useful for small accessible tracts where a market for fuelwood exists. This system favors selected crop trees (i.e., standards) for the production of high value timber or veneer logs while periodically removing all other merchantable trees. Harvests at 10-20 year intervals provide the landowner with flexibility to accommodate market conditions and growth. Reserve trees are kept free-to-grow to obtain maximum size, provide mast for wildlife purposes, and aesthetic reasons. The regenerating forest is primarily of sprout origin, even aged and dense, ideal habitat for game birds and other species. Landowners such as game clubs and wildlife preserves can use this method effectively to achieve a mix of objectives in which income from forest products is helpful, but other objectives are more important. This method can also be applied effectively in a forest managed for fuelwood. The pleasing visual mix of mature trees, small sawtimber, and poles with a scattering of shrub patches may make this the ideal method for landowners desiring both continual forest cover and periodic income. Initiating this treatment requires selection of approximately 55 standards (potential crop trees) per acre from existing pole and sawtimber. The goal is to have an even distribution of diameters over all classes. At each harvest, eight to ten new standards per acre are chosen in the pole size class. Concurrently, one fifth of the largest crop trees are harvested along with all other stems larger than 5 inches dbh.

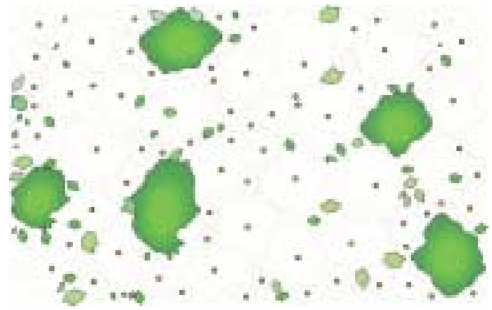
Advantages

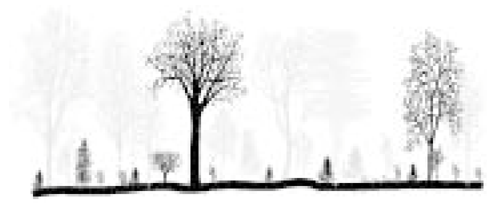
Maintains continuous forest cover with low visual impact; Periodic income for forest owner; Harvest schedules can be adjusted for market conditions; Provides regeneration conditions favoring midtolerant species; Reserve trees will be very large at end of next rotation

Disadvantages

High skill required for successful implementation; Higher costs for inventory, marking, and harvesting; Lower yield at each harvest entry; Increased taper of main bole may decrease grade volume; Large crowns may damage other trees when harvested

Reserve Tree/Seed Tree. The reserve, or seed-tree method is like a clearcut, although more aesthetically pleasing, in that not all the overstory vegetation is removed. Borrowing an idea from the shelterwood method, a few trees are left scattered in the stand to provide a source of seed. The residual trees should be chosen from the healthiest and best seed producers in the stand. The main difference between this 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, or seed, trees are retained because other sources for new seedlings may not be reliable, and generally they are kept in the new stand until the time of the first commercial harvest. The new forest will be composed mainly of offspring from the reserve trees, and some habitat enhancement value from retaining these large scattered trees can be realized as well.





Reserve tree method

Advantages

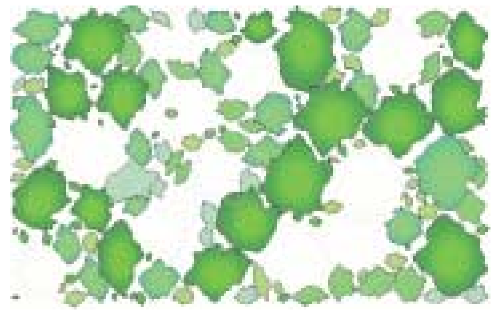
Aesthetically more pleasing than a clearcut; Provides regeneration conditions similar to a clearcut (i.e., beneficial for mid- and intolerants); Reserve trees will be very large at end of next rotation; Provides roost trees for raptors and other birds; Reserve trees serve as a supplemental seed source,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

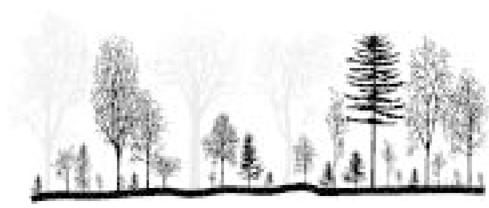
Disadvantages

Reserve trees susceptible to windthrow and lightning damage (and lost volume); Crown breakage of reserve trees (see above) can damage smaller regeneration; Large crowns of reserve trees may damage other trees during next harvest operation; No income for 30-40 years

Beware!

Diameter Limit/High Grading. All too often a high-grade is disguised as a "selection" harvest where the most profitable trees are removed with little, or no, consideration given for future conditions. High-grade cutting, regardless of how "light" the cut is, has a negative long-term impact on both economic value and on forest health. Diameter limit cutting may appear to be a sensitive method, cutting the largest trees to release smaller, younger trees. Landowners are 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.





Diameter limit harvest

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. Cut or girdle all trees with poor form and low vigor. Trees with poor form will develop into wolf trees that prevent the development of more valuable regeneration. Trees with poor form are also more susceptible to damage from wind, ice, and snowstorms. Trees with low vigor grow slowly and are susceptible to insect and disease infestations.

Marking a diameter limit cut is simple. All merchantable trees larger than a certain diameter are harvested. The landowner may have to wait decades 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 diameter) are slower growing, less valuable maple and birch.

Beware!

Advantages

Harvesting method generates highest short-term income; Minimal skill and cost required; Increased proportion of cavity and den trees; Increased vertical structure heterogeneity

Disadvantages

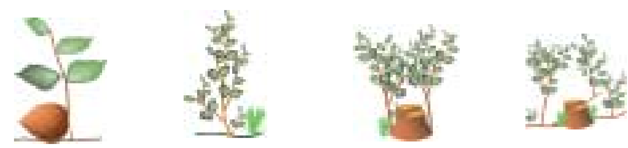
Long-term loss of fiber productivity and increased harvest intervals; Increased proportion of cull and slow growing trees in stand; Increased potential of damage to residual trees; Loss of valuable midtolerant species (e.g., oaks); Detrimental to wildlife species requiring early successional habitat

Species regeneration notes

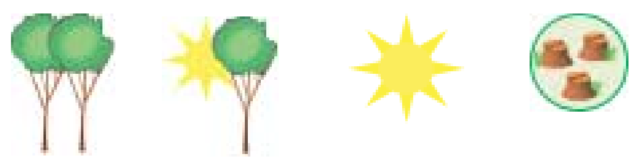
The following pages outline the general requirements for successfully regenerating some species groups (e.g., oak, map). The first page of each species group gives some background information on history, distribution, and mature size. This page also notes the commercial, ecological, and aesthetic value of the species group. The second page provides information on regenerating selected species. This section is meant as a general guide and starting point for discussion with a professional forester. The meaning of the symbols used in this section is given below. Specific guidelines will depend vary by species (i.e., northern red oak vs. scarlet oak), local soils, and other factors.

Seed dispersal mechanisms: Tree species utilize a variety of mechanism 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.

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.



Light requirements: The relative minimum requirement for sunlight varies among species. Tolerant species can survive and grow in full shade. midtolerants in partial shade, and intolerants only in full sunlight. Some species require clearcutting to develop into mature trees.



Special considerations: This section provides information on some problems that 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. This wounding increases the possibility of heart rot.

Oak (*Quercus* spp.)

Oaks dominate the landscape throughout most of Connecticut. Oaks are disturbance-dependent species and most of our oak forests arose on lands that were repeatedly burned and harvested prior to 1900. Native Americans would soak the acorns in streams during the winter to remove the tannins that made them inedible. 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 Connecticut's most valuable timber tree in both value and volume (19% of total).

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.

Wildlife
Acorns are used by many species, including white-tailed deer, turkey, squirrels, chipmunks, and blue jays. White and chestnut oak acorns, because of their lower tannin content, are eaten before the acorns of other species.

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

Oak (*Quercus* spp.)

Seed dispersal

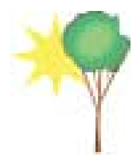
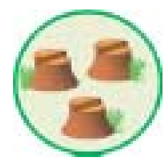
Oaks produce large seed crops at 2-10 year intervals. The large acorns that are dispersed by blue jays and small mammals germinate in the spring.


Reproductive modes

Successful oak reproduction develops from stump sprouting and from advanced regeneration (seedlings with root systems that are 5-20-years old).

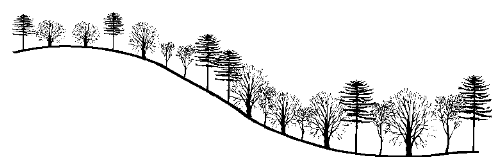

Light requirements

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

Site requirements

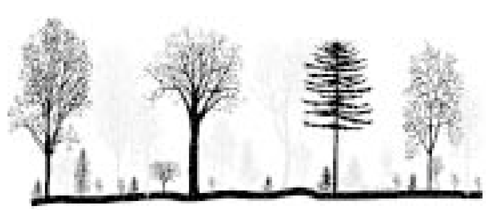
Northern red oaks grow on good to average quality sites common to middle and lower slopes. Black and white oaks are on middle slopes with average site quality. Chestnut and scarlet oaks grow on low quality sites on upper slopes and ridgetops.



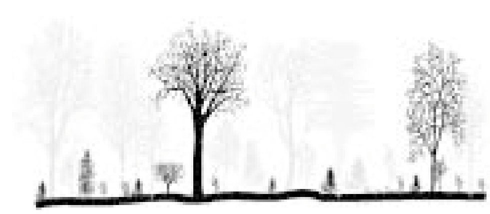
Special considerations

Oaks need protection from browsing where deer herds are large. Prescribed burning can enhance seedling height growth.


Best methods successfully regenerate oak



Shelterwood method



Reserve tree method

Maple (*Acer* spp.)

Red maple has become the most common tree in Connecticut, accounting for one-quarter of all 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) allow 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 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.

USES

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

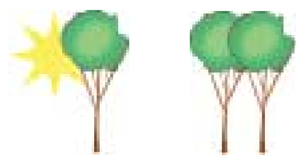
Wildlife
The large hollows commonly found in centenarians are favorite den sites of raccoons, porcupines, and flying squirrels. Chickadees, wrens, and cardinals eat the seeds and deer will eat the leaves and twigs.

Aesthetics
The early kaleidoscope of fall colors in red maple swamps herald 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.

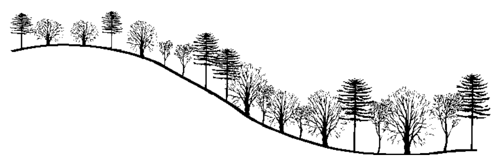
Seed dispersal
Sugar maple produces large amounts of winged seeds (samara) at 3-7 year intervals, red maple about every other year. The seeds are primarily dispersed by the wind.

Reproductive modes
Both species depend on advanced regeneration that develops after partial cutting or gaps creating 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 southern New England. Red maple is competitive in partial shade created by partial cutting.

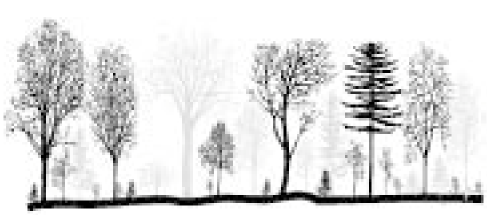


Site requirements
One of the reasons that red maple continues to increase in southern New England is its ability to grow on all but the driest and wettest of sites. Sugar maple regeneration is found on lower slope positions where soil moisture is adequate. There is some evidence that its distribution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

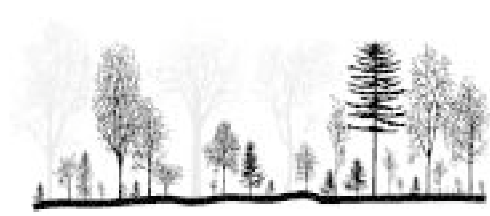


Special considerations
Although logging damage rarely kills maples, it often creates wounds that cause extensive internal rot. Both species are weakened by wildfire.

Best methods to successfully regenerate maple



Single tree selection



Diameter limit harvest

Eastern White Pine (*Pinus strobus*)

Eastern white pine can grow on sites ranging from dry ridgetop to swampy valley. In 1710, the English Parliament passed the *White Pine Act* to protect the large white pine needed for masts. Although largely ineffective, this was one of the first acts that set colonists and England on a collision course.

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

USES

Wood products
Furniture, lumber, bark mulch, ship masts.

Wildlife
Where eastern white pine is not common, deer will eat needles and terminal buds of seedlings and saplings. Red-breasted nuthatches both eat pine seeds and nest in cavities. Red squirrels also eat pine seeds by methodically dismantling the cones.

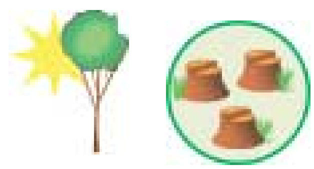
Aesthetics
Mature eastern white pine stands with their massive boles soaring high above inspire a sense of awe and reverence, especially when the wind whispers through the needles. The green of scattered pines accent fall colors and provide a reminder of life during the monochrome months of winter.

Eastern White Pine (*Pinus strobus*)

Seed dispersal
Eastern white pine produces large amounts of seeds at 3-10 year intervals. The seeds are dispersed by the wind in the fall.

Reproductive modes
Successful white pine reproduction can be obtained 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 multi-aged stand management.

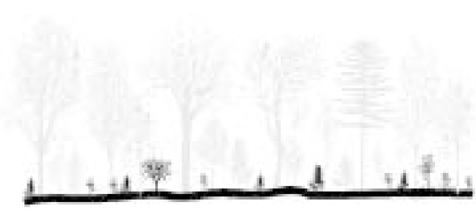
Light requirements
Although eastern white pine seedlings can grow in partial shade, eventually overstory removal (final stage shelterwood or clearcutting) is necessary for seedlings to develop into mature trees.



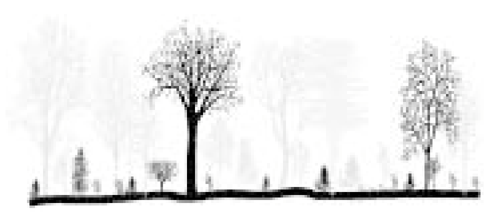
Site requirements
Eastern white pine can be found in every site from deep sands to swamps. However, regeneration success is best on sites that are droughty at some period during the year.

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 white pine

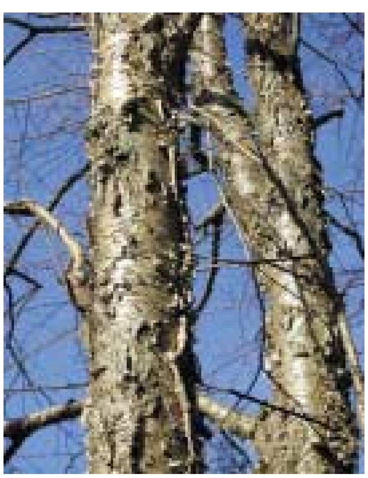


Silvicultural clearcut



Reserve tree method

Birch (*Betula spp.*)



Black birch is often found on average sites, and yellow birch on moist to wet sites, throughout the state. Black birch is now the second most common tree species in Connecticut. Both species 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.
Many of the larger black birch trees have one or more large cankers that reduce the potential economic value of this species. Although both species can survive for 200 years, maximum ages of about 120 are more typical. Mature trees are commonly 80 feet tall, with diameters slightly larger than a foot.

USES

Wood products
Veneer, lumber, railroad ties, pallets, and firewood.

Wildlife
The seeds of these trees provide some winter food for chickadees, ruffled grouse, and chipmunks. The bark of yellow birch is utilized for nesting material by some birds.

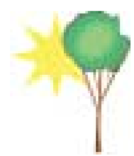
Aesthetics
The golden fall foliage of birch leaves adds gaiety to autumn landscapes. The frilly, peeling light-colored bark of yellow birch is a unique feature of moist woodlands

Birch (*Betula spp.*)

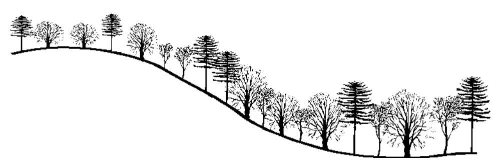
Seed dispersal
Black and yellow birch produce large amounts of seeds at 1-2 year intervals. The small seeds are dispersed 300 feet or more across crusted snow by the wind in mid winter.

Reproductive modes
Successful birch reproduction can be obtained from seedlings in large openings or clearcuts. Black birch can also produce successful regeneration in openings created by shelterwood operations.

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

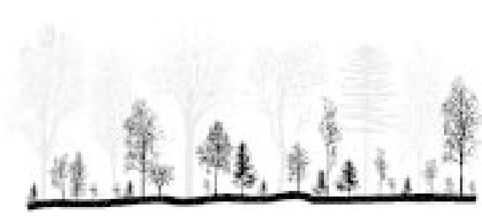


Site requirements
Black birch is commonly found on average quality sites; yellow birch on moister sites. In the northern part of the state, black birch is found towards ridgetops and yellow birch on midslopes.

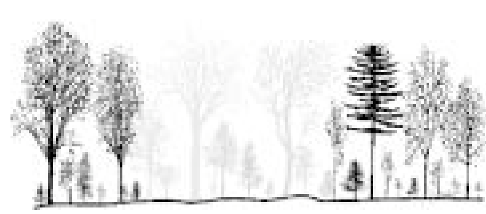


Special considerations
Both black and yellow birch are very susceptible to fire and logging damage. Although nectria canker is common on black birch and can make the wood unmerchantable, it rarely kills seedlings.

Best methods to successfully regenerate black and yellow birch



Commercial clearcut



Group selection

American Beech (*Fagus grandiflora*)

Beech is a common species in forest preserves and high-graded stands. It is a slow-growing, long-lived species (when not infested with beech bark disease), and 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. 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

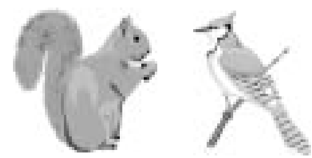
Wood products
Furniture, chopping blocks, baskets, railroad ties, pallets, and firewood.

Wildlife
American beech seeds provide food for large animals such as black bears and small animals such as white-footed mice. A variety of birds also eat the seeds.

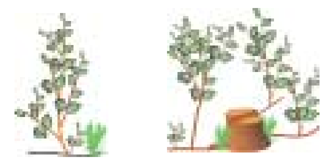
Aesthetics
The distinct smooth bark is an easy identifier for beech. Young lovers have been known to carve testimonials to their everlasting devotion in the bark of beech trees, though whether this contributes to the aesthetics is questionable. Few herbaceous plants grow in the deep shade of a beech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

American Beech (*Fagus grandiflora*)

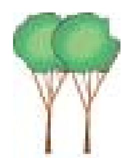
Seed dispersal
American beech produces large seed crops at 2-8 year intervals. The medium sized seeds are dispersed by blue jays and small mammals.



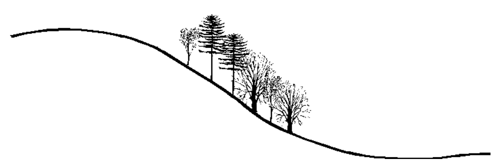
Reproductive modes
Successful American beech reproduction develops from root suckers and advanced regeneration. Beech seedlings can persist in the understory for decades.



Light requirements
American beech is among the most shade tolerant species in southern New England and can develop in all but the darkest shade.

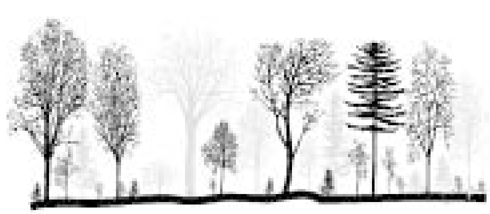


Site requirements
American beech regeneration is found on midslope positions where soil moisture is adequate. It is also found on lower slopes and benches.

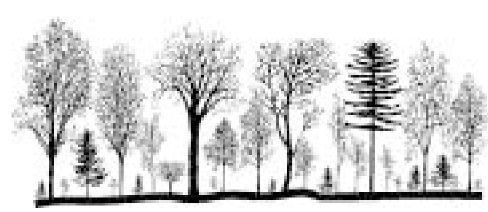


Special considerations
Logging damage can create wounds that cause extensive internal rot. Beech bark disease can stunt growth of saplings and causes deformed growth.

Best methods to successfully regenerate American beech



Single tree selection



Unmanaged forest

Photo Credits t-top photo, m-middle photo, b-bottom photo

J.P. Barsky: 11m. 14mb, 17t, 22m, 25b, 26b, 27b, 30b, 32b, 34tb, 36t, 38tm, 40t, 42tm; Fred Bormann: 10mb
CAES historical archives: 4tm, 5m,b, 6t, 10t, 7t, 19b, 20m, 23t; CT DEP, Division of Forestry: 20m, 22t
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A special thanks to Hull Forest Products for permission to photograph their mill operations (page 11). We would also like to thank J.P. Barsky, M.J. Bartlett, G. Milne, D. Beers, and J.E. Gillespie for their helpful comments

An expanded version in electronic format is available at:

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