Limiting Factors

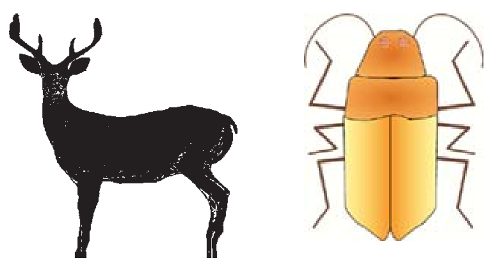
Trees and stands of trees are able to survive and grow under unique combinations of environmental conditions (e.g., nourishment, moisture, light and space). Different types of trees or stands require different combinations of these factors depending on their particular adaptations. Healthy, productive 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.

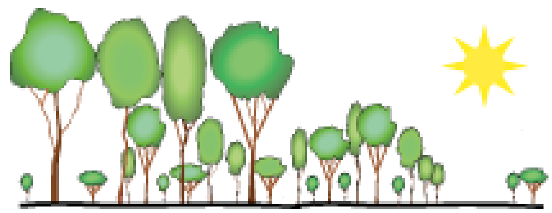
The manner in which these factors interact at the scale of the seedling will determine the ability of seedlings to germinate, become established, survive, and grow. Among the factors affecting growing conditions at any site, the one that, if increased, will result in the greatest corresponding increase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

ABIOTIC FACTORS

BIOTIC FACTORS

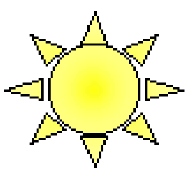
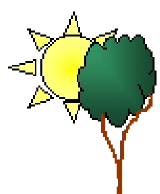
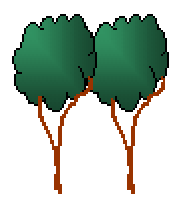


Light and Space. All growing plants require sunlight for photosynthesis…trees included! For most tree species in the Northeast, light availability is the most limiting factor to successful regeneration. Species that compete best in full sunlight have the capacity for rapid height growth and are often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

Limiting Factors

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. Nutrients 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.

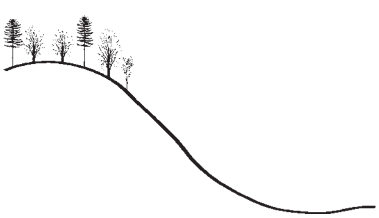
The undisturbed forest floor consists of a thick layer of leaf litter on top of a loose friable soil that is high in organic matter and securely bound by tree roots. It has a tremendous capacity to absorb rainfall. Overland flow or runoff is a rare event in the forest, and significant erosion is virtually 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.

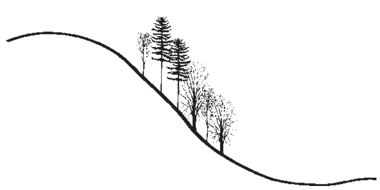
Limiting Factors

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”.

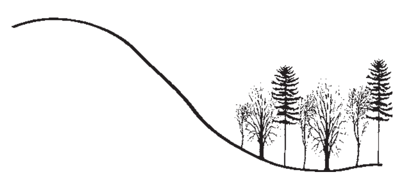
Less obvious, perhaps, is the fact that environmental conditions considered favorable for one species may be unfavorable for another, so any discussion of site quality must be made in the context of a particular species or species mix (forest type). In Connecticut, trees are almost everywhere except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

Limiting Factors

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.

Disturbance–The Agent of Change

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.

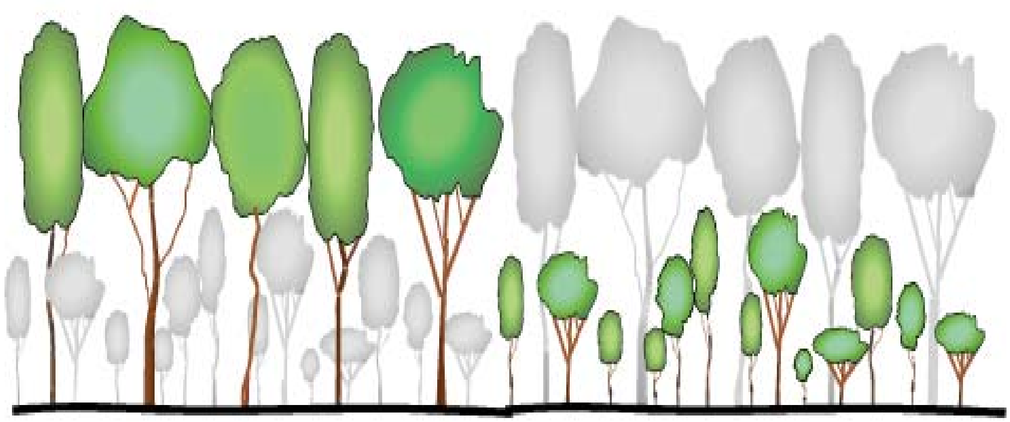
Properly conducted, most harvesting methods mimic a natural disturbance. Ideally, the forester will first ascertain the long term management goals of the landowner and then prepare a management prescription to achieve those goals. An integral part of the management plan is to determine a species mix 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.

Disturbance intensity can range from single tree mortality (top), to small windthrown groups (middle), to complete stand removal (bottom).



LOW (UNDERSTORY)
DISTURBANCE

HIGH (OVERSTORY)
DISTURBANCE

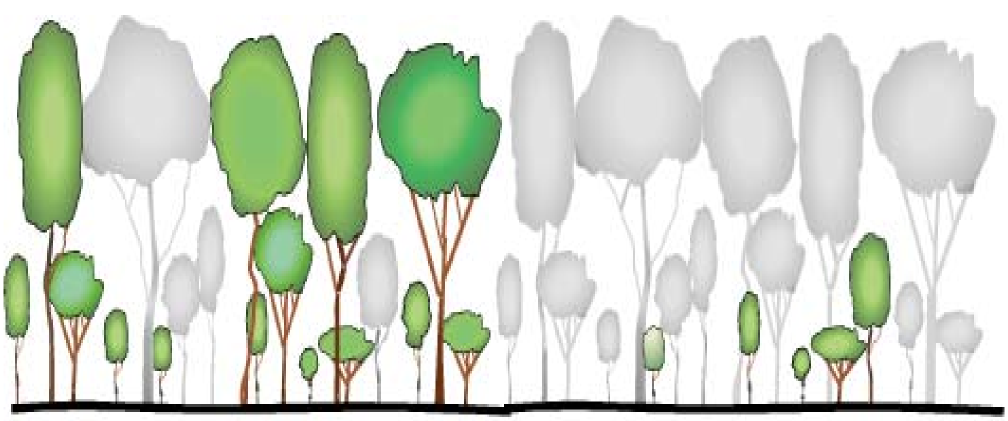
Disturbance–The Agent of Change

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