PB 1751

A TENNESSEE LANDOWNER AND PRACTITIONER GUIDE FOR

ESTABLISHMENT AND MANAGEMENT OF SHORTLEAF AND OTHER PINES

Real. Life. Solutions.™

UT EXTENSION
INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

Contents

Compiled and Edited by David C. Clabo and Wayne Clatterbuck

This publication is an update of University of Tennessee Extension publication PB 1751 that was printed in 2005. The focus of the update is to provide more information about the establishment and management of shortleaf pine among the pine species that occur in Tennessee.

Printing of this publication is partially funded by grants with the National Fish and Wildlife Foundation and International Paper through the Cumberland Plateau Forest Stewardship Fund; the Shortleaf Pine Initiative; and the Tennessee Department of Agriculture, Division of Forestry and the USDA Forest Service.

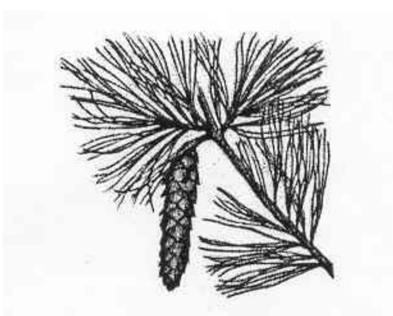
Purpose

Forests greatly impact the environment and the economy of Tennessee. The wood products industry contributes more than $21 billion annually to the state economy and employs 184,000 workers.[1] Tennessee's forests provide clean water and abundant wildlife habitat that support the $2.5 billion annual hunting and fishing industry according to the Tennessee Wildlife Federation. Scenic beauty and opportunities for outdoor forest recreation contribute to the $16.7 billion per year tourist industry in Tennessee (Tennessee Department of Tourist Development 2015) and the high quality of life enjoyed by Tennesseans. More than half of the Tennessee landbase, about 14.4 million acres, is forested, and approximately 80 percent of these lands are owned by private, nonindustrial landowners. Tennessee consistently ranks as being one of the nation's largest producers of hardwood timber. Even so, 1.8 million acres of our forests are composed of pine or pine-oak cover types.

These pines contribute not only to a diversity of products that can be commercially marketed, but also increase the wide array of recreational and wildlife opportunities that make Tennessee a unique environment. With the 50 percent decrease in pine and pine-oak acreage since 1950, more interest has been created to enhance the limited, but valuable, pine resource in Tennessee.

The primary focus of this publication will be on shortleaf pine, the most common and widespread pine in Tennessee, but also the pine species that has diminished the most in acreage. Shortleaf pine is a component of several community types from open savannas and woodlands to pine-hardwood mixtures to intensively managed plantations. The other pine species are added for reference and comparison to shortleaf pine.

This booklet was written as a cooperative effort between University of Tennessee Extension, the Shortleaf Pine Initiative, the National Fish and Wildlife Foundation, and the Tennessee Department of Agriculture-Division of Forestry to assist Tennessee landowners in managing their pine resource, whether 5 or 500 acres. Our hope is that this reference will help landowners make sound management decisions, consider managing for pines on lands best suited for the resource, and maintain a healthy pine ecosystem. However, the guide will not replace the expertise that can be gained from working with professional foresters.



[1] *University of Tennessee Institute of Agriculture Agri-Industry Modeling and Analysis Group*

Pines of Tennessee

UT Extension Staff
Forestry, Wildlife and Fisheries

With more than 14.4 million acres in Tennessee, forests comprise 55 percent of the land. There are 178 native tree species on the landscape, with nearly 80 percent of the forest in hardwoods such as oaks, hickories, maples and yellow-poplar. The remainder of the forest is a mixture of hardwoods and softwoods, or pure stands of softwoods, including six species of pine. While not a large component of the resource, the pine species add diversity to both the landscape and the economic market.

Shortleaf Pine – *Pinus echinata*

Shortleaf pine was once the dominant pine species in eastern Tennessee prior to the planting of loblolly pine and fire control programs. The species now exists only as remnant groups and individuals primarily on the Highland Rim, Cumberland Plateau, Appalachian Mountains, and the Ridge and Valley. On the dry, better-drained ridgetops, shortleaf pine will associate better with hardwood species than will loblolly pine.

A slow-growing species compared to other pines, shortleaf begins its life as a semi-shade-tolerant species capable of establishing itself under sparse competition. It has demonstrated a consistent diameter growth pattern in areas where it grows in East Tennessee. Once reaching dominant and codominant crown position, the species will maintain itself in the stand. Currently, the shortleaf pine resource is in danger of disappearing from the Tennessee landscape because of the absence of regular fire occurrences that encourages regeneration and the length of time between adequate seed production.

Shortleaf pine's slow initial growth is due to the development of a deep taproot system that allows the species to exist on poorer sites. Although shortleaf pine can be harvested for pulpwood, today's economic climate makes shortleaf pine a more suitable sawtimber commodity. The tight, dense wood and lack of taper makes shortleaf pine ideal for the log home industry. Faster-growing loblolly pine is the choice for most pulpwood rotations.

Shortleaf pine is susceptible to littleleaf disease in flood-prone or poorly drained clay soils and the southern pine beetle; however, it shows the most resilience to ice damage with respect to the other southern pines. Ground fire is viewed as an asset in shortleaf pine areas, improving the seedbed conditions and eliminating competition. The species is unusual in its ability to sprout from the root collar when mortality occurs, a trait seen in individuals as large as 8 inches in diameter.

Loblolly Pine – *Pinus taeda*

Loblolly pine is the most important economic pine species in Tennessee. Southwide, loblolly comprises more than half of the standing pine volume. With the widespread planting of loblolly pine, the species has been able to adapt and become naturalized in most areas.

Loblolly pine, like most southern pines, is shade-intolerant and focuses a majority of its initial growth on height accumulation. Seedling growth and development is rapid, since it is an early successional species. Over time, associated hardwoods such as oak and hickories will develop in the understory of loblolly pine stands. Loblolly pine can be established on a wide variety of soils, and under most conditions it will grow into the upper canopy on these sites unless seedlings are inhibited by competition from vines, herbaceous plants, or other shade-intolerant species. Loblolly pine is a "plastic species" capable of occupying a wide range of soils and site conditions.

Loblolly pine is very susceptible to ice damage, southern pine beetle infestation, and, at young seedling/sapling stages, fire. Fire should be suppressed until the trees are several inches in diameter and 20 feet tall.

Loblolly pine is intensively managed in pine plantations, where thinning, fertilization and prescribed fires have all shown improvements in the growth and volume of the stand. Pulpwood and sawtimber products can be grown in relatively short rotations, compared to other pines, under these intensive regimes. Plantation establishment is generally a process of eliminating competing vegetation through fire and herbicide treatments followed by the planting of genetically improved stock. However, natural regeneration processes are also successful in areas with a viable seed source and bare mineral soil. Naturally regenerated lands may require precommercial thinning operations to reduce the growing stock.

White-tailed deer, squirrels and bobwhite quail use loblolly pine stands. Wild turkeys do particularly well on large tracts of mature loblolly where openings have been created through thinnings and fire. The pine warbler, brown-headed nuthatch and Bachman's warbler all make their nests in natural and intensively managed stands.

Virginia Pine – Pinus virginiana

Once described as a "forest weed," Virginia or scrub pine is a short-lived, common pioneer species on Tennessee's landscape. Virginia pine occurs on soils with a variety of acidities ranging from pH of 4.6 to 7.9. The soils under a Virginia pine stand are generally more acidic than those under loblolly, shortleaf or white pines.

Virginia pine is an extremely shade-intolerant species, producing heavy seed crops every three years. With its rapid early seedling growth, Virginia pine is the ideal pioneer species, dominating abandoned fields quickly. It can tolerate dry, poor soils and drought conditions better than most pines in the region.

Ice storms can eliminate a Virginia pine stand. The species' susceptibility to heart rot generally relegates Virginia pine as pulpwood commodity in the region. Fire is a serious threat to seedlings and young saplings and should be suppressed early. Thinning is not suggested as a treatment in older Virginia pine stands, due to the windthrow potential resulting from shallow root systems. Recent research has also indicated that Virginia pine may be the pine that is most susceptible to ozone pollution.

Virginia pine is the most preferred Christmas tree species of the southern pine species, but its value in Tennessee is stabilization of mine spoils on strip-mined sites. The rapid establishment of the species and its resilience with respect to the soil's acidic conditions helps prevent erosion and return vegetation to these highly altered sites. The species provides winter cover for many fauna. Woodpeckers favor Virginia pine for nesting cavities as individual trees mature and the wood becomes susceptible to fungal decay.

Eastern White Pine – *Pinus strobus*

Eastern white pine was once the pine sought by the British navy for use as ship masts. The species is now used in the log home building industry in Tennessee due to its remarkable durability and ease of wood working. White pine is also favored as a Christmas tree species.

The species occurs in patches and strips along the Cumberland Plateau and the ridges and mountains of the Appalachians. It is intermediately shade-tolerant, allowing it to reproduce under hardwood stands as well as replace itself. Favored as a sawtimber species, early growth is relatively slow during the first three years. Once established, height growth can be as rapid as 3 feet annually.

There are a number of diseases and insects that impact eastern white pine, such as white pine blister rust, the white pine weevil and the southern pine beetle. The species will also not tolerate prolonged heat or droughty conditions, preferring moist and cooler sites at the higher elevations. White pine plantations are not as popular as loblolly pine due to the limited markets in the area, cost of seedlings and a limited seedling supply.

The species is also a poor self-pruner. Dead branch whorls remain on tree boles for years after the needles have fallen off. Many species of wildlife use the dense crowns and branches for protection and cover, especially in areas of heavy snowfall.

Table Mountain Pine – *Pinus pungens*

Table Mountain pine occurs on xeric sites in the upper Appalachian Mountains, especially on rocky and shale-littered soils. An Appalachian endemic, the species depends upon heat from fires to open its serotinous cones for seed distribution. These trees do not tolerate shade. Table Mountain pine establishes on exposed soils after a major stand disturbance such as fire.

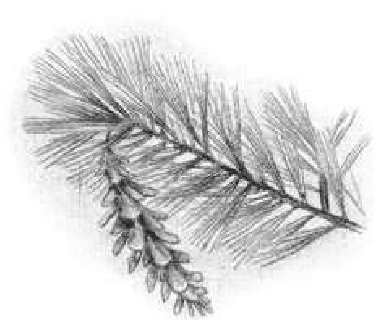
The suppression of fire has limited the distribution of seed from the serotinous cones, and the species is in decline. The species can be used commercially for pulpwood, but the resource is so limited in size and abundance that its importance is more for stabilizing soils and minimizing erosion from the exposed rocky topographic landscape of its range.

Pitch Pine – Pinus rigida

Pitch pine can be found in the mid-elevations of the Appalachian Mountains in East Tennessee. The cones of the species are semi-serotinous, requiring fire or heat to open them. Because of the large amount of resin produced by the tree, the wood of pitch pine is highly resistant to decay. This dense, resinous wood makes it useful for construction, mine props, railroad ties and fencing.

Pitch pine is best maintained on less fertile, sandy sites where fire commonly occurs. The seed needs a bare mineral soil to germinate and fire to promote cone opening. Pitch pine is very fire resistant, sprouting after upper stem mortality much like shortleaf pine. However, in areas where severe fire is repeated, pitch pine will dominate shortleaf pine due to increased seed production.

Like Table Mountain pine and shortleaf pine, pitch pine populations are in decline in Tennessee due to decades of successful fire suppression programs.



Identification, Ecology and Silviculture of Shortleaf Pine

David Clabo, Graduate Research Associate
Wayne K. Clatterbuck, Professor
UT Forestry, Wildlife and Fisheries

Shortleaf pine (*Pinus echinata*) has the widest native range of the southern pine species and is found in 22 states from Texas to New Jersey (Figure 1) (Guldin 1986, Oswalt 2012). Stands of shortleaf pine are more prevalent west of the Mississippi River in Arkansas and northern Louisiana where precipitation and competition from mesic hardwoods are much less than east of the river. Tennessee has an estimated 437 million cubic feet of shortleaf pine standing volume while loblolly pine has an estimated 963 million cubic feet of standing volume. By comparison, upland hardwoods, which includes white oaks, red oaks, hickories, yellow-poplar, hard maples, soft maples and beech have an estimated standing volume of 19.5 billion cubic feet as of 2012 (FIA 2012, Moser et al. 2007).

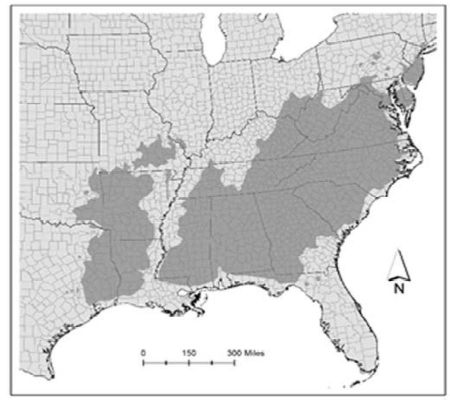


Figure 1. Range map displaying the 22 states containing shortleaf pine (Little 1971).

Many different sites are conducive to shortleaf pine establishment and growth, but regions that receive 45 to 55 inches of rainfall per year are most favored. Growth is best on sandy loam or silt loam textured soils usually found in lowlands, but the species is most frequently found growing on soils from the order ultisols on relatively dry, rocky uplands. Shortleaf pine is not tolerant of high pH or high calcium content soils. Elevations where shortleaf pine occur range from sea level to approximately 3,300 feet in the southern Appalachian Mountains. Site indices for shortleaf pine range from 30 feet to 85 feet at base age 50 years for natural stands throughout the region (Figure 2). Site index curves for shortleaf pine plantations in central Tennessee are presented in Figure 3. Shortleaf pine seedlings grow slowly their first 1 to 3 years while a large taproot develops (Lawson 1990). Height growth of shortleaf pine is 1 to 3 feet per year if average precipitation amounts occur (Hardin et al. 2001). Crown expansion stops by early to mid-July each season, unless adequate precipitation occurs late in the summer.

Shortleaf pine is considered intolerant of shade, but young seedlings will survive in shade with reduced growth rates for a period until they are released. Shade tolerance decreases as trees increase in size and age. On productive sites, shortleaf pine may reach heights of 130 feet tall, 40 inches in diameter, and may live for 170 years or longer. Reproduction may be either by seed or by sprouting. In most instances, trees will not produce seed before age 20 or 8 inches in diameter at breast height. Seed is mostly disseminated in the fall, and seeds germinate the following spring (Lawson 1990). Achieving shortleaf pine regeneration from seed can be difficult if seedbed and climatic conditions are unfavorable after sufficient seed crops. Bumper seed crops are sporadic and can occur every three to 10 years (Lawson 1990). Seeding distances for mature trees are typically 200 to 300 feet downwind from the source and 75 to 100 feet in other directions (Baker 1992).

Sprouting occurs when the stem is damaged by disturbances such as fire or herbivory. Sprouts originate from dormant buds that exist on the root collar just above a section of the taproot known as the basal crook. The basal crook is a portion of the taproot that turns from vertical to horizontal back to a vertical orientation again. The basal crook begins to develop two to three months after germination in seedlings grown in full sun. Seedlings grown in shade may not develop a basal crook at all. This unusual growth characteristic of the root is believed to be a fire adaptation (Lilly 2011). Sprouting capability decreases in shortleaf pine with age, increasing size, and rarely occurs above 8 inches in diameter. The season of disturbance results in minimal differences in the survival of young seedlings, although hotter, more intense burns during the growing season may result in greater mortality (Clabo 2014).

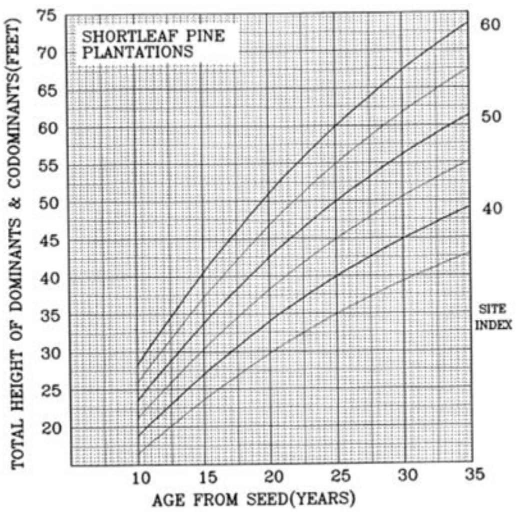


Figure 2. Site index curves for shortleaf pine plantations in central Tennessee, northwest Georgia and northern Alabama at base age 25 years (Smalley and Bower 1971).

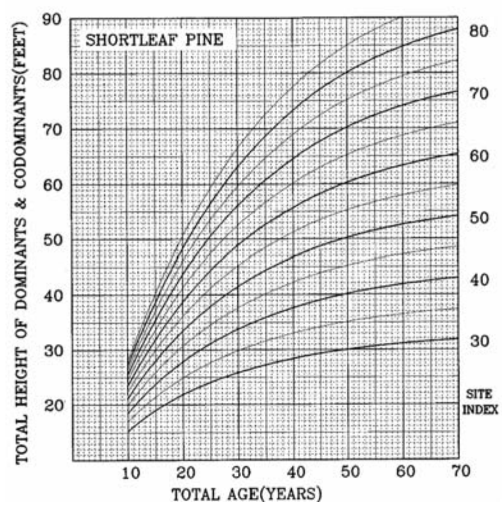


Figure 3. Site index curves for naturally regenerated shortleaf pine in southeastern Missouri at base age 50 years (Nash 1963).

Features of shortleaf pine that differentiate it from other conifer species found in Tennessee, such as loblolly pine and Virginia pine, include needle, cone, bark and form characteristics (Table 1). Shortleaf pine needles range from 2.75 to 4.75 inches long, which is shorter than loblolly pine needles and longer than Virginia pine needles. Needles are connected to the fascicles in bundles of two or three, and the needles do not twist around one another as they do in Virginia pine. Shortleaf pine has small 1.5- to 2.5-inch cones. Cones are ovoid to oblong in shape (egg shape), reddish-brown in color, and have spiked umbos or scales. Cones typically remain attached to the tree for one to three years even after seed has been released. Seeds are small and have wings to facilitate dissemination. They are approximately 3/16 inch long and brown with black markings. The wings are approximately 1/2 inch long. In young trees, bark is dark and scaly, whereas in older trees, the bark is reddish-brown and forms irregular rectangular flat plates. The phellogen layer (or layer just inside the bark) is ivory white in color (Hardin and Harrar 2001). The branches of shortleaf pine prune better than loblolly, Virginia or pitch pine. The tree typically grows very straight. Young trees have conical crowns, while older trees develop more open crowns.

Table 1. Key identification features of shortleaf pine, Virginia pine, and loblolly pine.

Trait	Shortleaf Pine	Virginia Pine	Loblolly Pine
Needles	2.75 to 4.75 inches long, mostly fascicles of 2 and occasionally 3, needles may arise from dormant buds on the bole, persisting 3-5 years	0.75 to 3 inches long, in fascicles of 2, twisted, persistent 3 to 4 years	4 to 9 inches long, fascicles of 3 (occasionally 2), sometimes twisted, persisting 3 years
Cones	1.5 to 2.5 inches long, ovoid-oblong to conical, nearly sessile; umbo dorsal and armed with a sharp, straight or curved, sometimes deciduous prickle	1.25 to 2.75 inches long, usually sessile, ovoid-conic; umbo dorsal and armed with a slender prickle	2.5 to 6 inches long, ovoid cylindrical to narrowly conical, sessile; umbo has a stout, sharp prickle
Bark	Small trees nearly black, roughly scaly, small surface pockets or holes; later reddish brown and broken into irregular flat plates; phellogen layers ivory white	Thin and smooth, eventually scaly-plated, reddish brown	Variable, young trees scaly and nearly black, later 3/4 to 2 inches thick, irregular, brownish blocks; phellogen layers slate-gray
Twigs	At first green and tinged with purple, eventually reddish brown becoming flaky in 3 to 4 years; buds with red-brown scales	At first green, becoming purplish and glaucous by the end of the season and through the first winter.	Yellow-brown or reddish brown; bud covered with reddish brown scales, free at the tips and not fringed
Bole & Crown	Straight boles and medium crown volumes	Curvy boles with persistent branches and smaller crown volumes	Straight boles and larger crown volumes
Site	Most all site productivities, but more prominent on medium to poor sites	Poor productivity sites	Medium to better site productivities

The Decline of Shortleaf Pine

An estimated 16-17 million acres of shortleaf pine cover types existed across its range in the southeastern United States in the early 1950s (McWilliams et al. 1986). The acreage of shortleaf pine has diminished greatly since then. As of 2010, the total forest acreage dominated by shortleaf pine is estimated to be 6.1 million acres, and most of this acreage is mature forests with a disproportionately small percentage in the seedling/sapling or pole sizes (Oswalt 2012). The decline of shortleaf pine can be attributed to preference for the planting of loblolly pine on previous shortleaf pine sites, urbanization, fire suppression, bark beetle infestations, and introgression or hybridization of shortleaf and loblolly pines.

Southern pine plantation acreages across the South have increased from 1.8 million acres in 1960 to 32 million acres by 2000, according to Wear and Greis (2002), but shortleaf pine has not been planted as frequently as loblolly, slash and longleaf pines. Beginning in the 1950s, loblolly pine was planted extensively across the southeastern United States due to its faster growth rates. Loblolly pine is frequently used for pulpwood in the paper industry and for structural lumber and sawtimber products. In the early 1970s, 2.7 million acres of loblolly pine plantations existed. By the mid-1980s plantation acreages increased to 5.9 million acres, and by 2000, over 16.9 million acres of loblolly pine plantations were present (Cost et al. 1990, Shultz 1997, South and Buckner 2003). Loblolly pine has been extensively planted north of its range on sites that previously supported shortleaf pine and Virginia pine, thus displacing shortleaf pine from those sites.

Urbanization and land use conversion of privately owned forest land are occurring at faster rates in the southern United States than any other region of the country. Losses from forest conversion have occurred in shortleaf pine forest types in Tennessee since the 1980s (Arnold et al. 2010, Oswalt 2012). Increases in population growth and land development are expected to continue. Conversions of forested, private lands will likely increase (Alig et al. 2004), impacting the amount of shortleaf pine acreage as well as all forest types.

Fire suppression and bark beetle outbreaks have probably had the greatest impact on the diminution of shortleaf pine forest types across the state. Fire suppression began with the Smokey the Bear campaign in 1944, and has been very effective at preventing anthropogenic fires. The number of burned acres in southeastern forests was more than 14 million in 1917 and was reduced to approximately 1 million acres by 2003. Fire creates seedbed conditions (exposed mineral soil) that improve the success of natural shortleaf pine regeneration, reduces competing vegetation especially if burns are completed periodically for a number of years, and can reduce the risk of harmful fungal and insect outbreaks by controlling their populations and culling unhealthy trees. Southern pine beetle (*Dendroctonus frontalis*) outbreaks from 1999-2002 affected about 350,000 acres of pine across Tennessee, including pine dominated forests in middle and east Tennessee (Cassidy 2005). Many of the impacted areas regenerated naturally to hardwoods because shortleaf pine advanced reproduction was not present in the understory, and no natural seed source was present (Oswalt et al. 2012, South and Buckner 2003). Unless natural disturbances or timber harvesting occur followed by site preparation for pine seed (if a seed source is present) or seedling plantings, these disturbed areas will remain as hardwood forests.

Introgression, or the flow of genes into a species through hybridization and backcrossing with another, has been documented in loblolly pine and shortleaf pine. Areas west of the Mississippi River in shortleaf pine's range have more reports of hybridization than areas east of the river. However, hybridization is still possible in Tennessee where large populations of the two species occur in close proximity to one another. Hybrid trees display morphological and physiological traits of both species. Hybrids display differences in height growth, basal crook development, fusiform rust resistance, bole form, and the ability to avoid ice/windstorm branch or stem breakage. Important traits of shortleaf pine that may be lost or decreased include sprouting capability following disturbance and water use efficiency or drought tolerance. Two possible explanations for hybridization include climate change resulting in similar flowering periods, which causes the overlap of female strobili receptivity to pollen produced by either species, as well as the proximity of intensively managed loblolly pine plantations to natural shortleaf pine forest types (Lilly et al. 2012, Tauer et al. 2012). Hybrid trees will likely be less fire- and drought-tolerant and display different wood and bole form qualities than pure shortleaf pine. Hybridization is a complicated issue to address, but two measures that can be taken to reduce the occurrence are avoidance of planting loblolly pine north of its native range in close proximity to areas of shortleaf pine and periodic, prescribed burns in areas suspected of having hybrid seedlings. Because hybrid seedlings are less tolerant of fire than pure shortleaf pine seedlings, burning on a regular basis may reduce hybrid occurrence (Lilly et al. 2012).

Fire and Shortleaf Pine

Shortleaf pine is considered a fire-tolerant species and has many traits that improve its chances of survival with burning. One trait is thick, platy bark that develops at a relatively young age and insulates the tree from higher temperatures during burns. Shortleaf pine has low amounts of flammable resins compared to many other tree species which reduces the amount of bole damage during a burn. The wood is resistant to fire scar rot as well, and the species has the ability to sprout vigorously after the main stem has been damaged or killed until it reaches about 30 years old (Guyette et al. 2007, Lawson 1990, Mattoon 1915). Fire history research has documented that shortleaf pine dominated forests in western portions of the species range experienced low intensity burns every two to three years prior to fire suppression. Frequent burning is recommended to promote pure shortleaf pine forests (Guyette et al. 2007).

Fire is the most effective and inexpensive tool to improve seedbed conditions for shortleaf pine regeneration. Bare mineral soil is required for seedling germination because seeds do not contain enough energy to extend their radicle or root through leaf litter, grass, etc. Because seed crops are difficult to predict, the best methods for increasing the stocking of shortleaf pine seedlings are securing advanced regeneration from previous years, planting supplemental seedlings, and maintaining suitable seedbeds through periodic prescribed burning (Guldin 2007). Research has shown that seedbeds can be receptive to shortleaf pine seed for up to four years following a burn depending on fire intensity and site/vegetation features (Stambaugh et al. 2007). Competition control through periodic burning is a strategy to improve shortleaf pine's competitive status on moderate and poor sites. Young eastern white pine, red maple and loblolly pine are vulnerable to frequent burning on these sites (Abrams 1998, Williams 1998). Research in the Missouri Ozarks suggests that a burn cycle of eight to 15 years may be optimum for recruitment of shortleaf pine into the overstory while limiting competing species (Stambaugh et al. 2007).

Shortleaf pine seedlings can survive fire if less than 60-70 percent of the crown is scorched during a burn (Cain and Shelton 2002, Walker and Wiant 1966). Greater scorch amounts will result in topkill of seedlings or saplings. In Tennessee, seedlings as young as 3 years old can survive burns without topkill at a rate as high as 68 percent (Clabo 2014). The factor that affects shortleaf pine sprouting most following burning is soil heating that impacts the roots and dormant buds. Many factors affect heat transfer into the soil such as litter depth, basal crook depth under the soil surface, mean surface temperatures, flame and fuel arrangements, bark thickness, fuel loading, and soil moisture levels (Lilly 2011). As long as roots and dormant buds remain below 120 to 140 F, survival is likely (Hare 1961). To avoid these lethal soil temperatures, burning after recent rain events and avoiding higher temperature summer burns are recommended. Burning in 1- to 3-year-old seedlings in Tennessee has better survival after early or late growing season burns than after summer burns (Clabo 2014). Burning can be used as a tool to promote shortleaf pine regeneration through sprouting on the landscape. Careful application and timing of burning may promote the species on suitable sites throughout Tennessee.

Regeneration of Shortleaf Pine Communities

Natural Regeneration

Shortleaf pine is well-suited for even-aged or uneven-aged management practices. Natural regeneration of shortleaf is feasible only if a significant, mature shortleaf pine component is near the area to be regenerated, a condition rarely occurring in most eastern areas of the shortleaf pine range, including Tennessee. Somewhat unpredictable and varying seed crops from year to year can make natural shortleaf pine regeneration methods challenging. Trees will not produce seed reliably until they are 20 years old or about 8 inches DBH (Baker 1992). Cones develop in two years, and most seed is disseminated during the fall and early winter months (Lawson 1990). In Tennessee, reliable seed crops occur every three to 10 years on average. Seed crops can only be ascertained during the current year or one year in advance based on cone counts and seed fall counts (Baker 1992). A seed crop of at least 50,000 seeds per acre is considered the standard to adequately stock a site that has received site preparation such as scarification by mechanical treatments or burning due to seed predation and unsound seed (Baker 1982).

In dense shortleaf pine stands with 90 square feet of basal area per acre or greater, thinning three to five years prior to a regeneration harvest may improve seed production. In stands where shortleaf pine comprises less than 50 percent of the stand, competing hardwood vegetation control becomes more important, especially on better sites. Herbicide treatment of understory and midstory undesirable hardwood species may greatly improve germination and survival rates of shortleaf pine seedlings on areas with site indices above 70 feet. The above factors must be taken into account to ensure a new shortleaf pine cohort prior to choosing a natural regeneration method.

The three even-aged natural regeneration methods most commonly used in shortleaf pine systems are silvicultural clearcuts, seed tree harvests and shelterwood harvests. The silvicultural clearcut method is the easiest of the three even-aged methods to implement. One important requirement of this method is that seed trees that will regenerate the clearcut area must be present in adjacent stands. In stands with numerous understory woody plants and large woody debris components present prior to harvest, prescribed burning will improve the site for seed receptivity after the harvest is completed. Small clearcut patches or strips should not be more than 8 to 10 acres in size, and the long axis of the cut should be perpendicular to the area with seed trees so that prevailing winds can disperse seed into the clearcut area (Baker 1982). Harvesting should be done simultaneously with natural seed fall in autumn or early winter if possible. Logging activity will typically scarify the harvest area enough for seeds to germinate. On moderate- to high-productivity sites, release treatments using herbicides or burning will be necessary to control competitive species for continued growth and survival of shortleaf pine. Clearcut areas provide early successional wildlife species suitable habitat but may be unappealing aesthetically to landowners and the public.

The seed tree regeneration harvest is suitable for areas that have vigorously growing, mature shortleaf pine trees already in the overstory. In stands with 90 square feet of basal area per acre or more, thinning the stand to 60-70 square feet per acre three to five years before the seed tree harvest will likely improve seed production on selected seed trees. This step is important for trees with small live crown ratios, a common condition of shortleaf pine trees in dense, crowded stands (Baker 1992). As with a clearcut, prescribed burning completed prior to the harvest leaving seed trees will improve seedbed conditions after logging is complete. With the seed tree method, eight to 20 well-spaced shortleaf pine trees per acre are the only trees left on site after the harvest. Windthrow is a risk with this method due to the increased exposure the seed trees encounter after logging. In addition, sites with thin or rocky soils or exposed sites on upland positions are more at risk for windthrow. The logging slash after harvest may provide breeding ground for harmful insects such as engraver beetles.

The shelterwood system leaves the most intact forest cover for shortleaf pine seedlings to germinate and grow. This method involves two or more cuts of the overstory and midstory, and maximum seed production occurs under an overstory of 20-50 square feet of basal area per acre where a majority of the basal area left is shortleaf pine (Baker 1982, Phares and Rogers 1962). The greater overstory densities left with this method will reduce competition from shade-intolerant species such as yellow-poplar or black locust, but will also decrease growth rates of regenerating shortleaf pine seedlings. In stands with a significant hardwood component, using herbicides after the first cut reduces the understory and midstory hardwoods along with some overstory trees depending on stand density, leaving primarily shortleaf pine and a component of desirable hardwood species. Prescribed burning can be used then to improve seedbed conditions and control less fire-tolerant vegetation such as eastern white pine. Once adequate seedling stocking is achieved, usually about 1,000 seedlings per acre, the overwood is removed with a second harvest. Site preparation with all even-aged methods is essential for natural regeneration of shortleaf pine.

Uneven-aged silvicultural systems can be used to regenerate shortleaf pine naturally. These systems are used when frequent harvest of sawlogs is a management objective. Stands that have three or more age classes present have an uneven-aged structure. Cutting is done in all age classes more frequently on better sites (three to 10 years) and less frequently on poorer sites (eight to 20 years), and poor quality or form trees are cut first, leaving better trees to grow and stock the stand (Baker et al. 1996). Cutting in all size classes is necessary to ensure each age class has growing space for continued growth and development. In western portions of the shortleaf pine range, single-tree selection and group selection have been used to regenerate shortleaf pine dominated stands. Group selection is the more appropriate of the two methods in Tennessee because the larger opening size allows shade-intolerant species like shortleaf pine the opportunity to grow while creating a more suitable seedbed for seedling establishment. Uneven-aged management is applied to stands with at least 45 square feet basal area per acre of merchantable crop trees. Group selection openings are typically one to two times the height of mature trees in the adjacent forest (Nyland 2007). There should be mature shortleaf pine to produce seed for the group opening in the forest surrounding the openings, and control of undesirable hardwood seedlings and sprouts should be implemented until shortleaf pine seedlings reach competitive sizes. Regular, periodic harvests make uneven-aged management attractive, but marking stands, establishing new seedlings after each harvest, and maintaining trees in all age classes makes this system difficult to implement.

Planned natural regeneration of shortleaf pine has not been effective. Bumper seed years are infrequent and erratic, bare mineral soil conducive for seed germination must be present, environmental conditions (weather/moisture) for germination of the seed and survival of the developing seedlings are often adverse, and other competing ground vegetation must be controlled to favor shortleaf establishment and growth. Often the bare mineral soil that was implemented for seed receptivity becomes overgrown in subsequent years if it does not coincide with a favorable seed year. Bumper seed year, exposed mineral soil, favorable weather conditions, and control of competing ground vegetation must coalesce to favor natural regeneration of shortleaf pine. These conditions rarely occur together and more often may be the exception rather than the rule in the successful natural regeneration of shortleaf pine.

Artificial Regeneration of Shortleaf Pine

Artificial regeneration of shortleaf pine can be accomplished by direct seeding or by planting container or bareroot nursery grown seedlings. Choosing a method depends on site characteristics, acreage to be reforested, economics, and the amount of effort willing to be put into a reforestation project. In Tennessee, locating shortleaf pine seeds for direct seeding can be problematic due to availability. Seeds may have to be acquired from other states, which may not be suitable for growth in Tennessee. Seed from latitudes north or south of Tennessee may not perform well. Container seedlings are also difficult to acquire and expensive to purchase and ship as they are not commercially produced in Tennessee. Bareroot seedlings are commercially available and may be the most practical method for planting large acreages.

Direct aerial seeding is typically used to regenerate large acreages that are relatively free of overstory trees and 200 acres or more in size. With direct seeding, site preparation that exposes mineral soil, quality seed with a high germination percentage, treatment of seeds with bird and rodent repellent, and vegetation control are essential for success. The two most commonly used and effective site preparation treatments are burning and mechanical treatments such as disking or root raking, if slopes are not excessive (Mann and Gwaze 2007, Russell and Mignery 1968). Pines established with direct seeding compared to planted seedlings usually have slower initial growth rates, unpredictable survival rates due to weather variability, and overstocking of seedlings such that precommercial thinning may be needed. Direct seeding is significantly cheaper and easier to implement on terrain that is difficult to plant or access than planting bareroot or container grown seedlings (Barnett et al. 1986, Mann and Gwaze 2007). However, risks for regeneration failure with direct seeding are much greater compared to planted seedlings.

Spot seeding is the most economical and effective method for small landowners who are interested in regenerating just a few acres. With spot seeding, seeds are sowed individually and spacing is controlled. Sowing can be completed in the fall if seeds are not stratified, or seed can be sown in late winter or early spring, if it is stratified. Three to five seeds are dropped at each prepared drill hole to ensure at least one seedling germinates at that location (Barnett et al. 1986). Site preparation and subsequent vegetation control are essential for seedlings to grow and develop after seed germination.

Planting seedlings, either container or bareroot stock, provides more control of stocking, prevents the need for precommercial thinning, and logistically makes commercial thinning and harvesting operations more easy to complete as the stand matures (Barnett et al. 1986). When available, container grown seedlings have been found to have better growth and survival than bareroot shortleaf pine seedlings (Barnett and Brissette 2004, Gwaze et al. 2006). Container seedlings have become more available in recent years as companies have increased the magnitude of commercial container seedling production, but availability in Tennessee is still limited. Container seedlings have at least two other advantages over bareroot seedlings. They can be planted by hand or machine when properly configured without causing damage to the root system. Second, the planting season for container seedlings is typically longer than for bareroot seedlings (Barnett and others 1986). The major disadvantages to container seedlings are the costs associated with purchasing them because they are typically more expensive than bareroot seedlings; the water potential differences between the container soil and the soil surrounding the seedling can result in the roots not spreading from the favorable medium of the container plug to the more adverse residual soil; and the long shipping distances of container seedlings could jeopardize seedling health and survival.

The success of bareroot shortleaf pine seedlings is dependent on choosing a suitable site, planting high quality seedlings, using proper planting techniques, and controlling competing vegetation after planting. Shortleaf pine can be planted on a variety of sites, but upland sites with drought-prone, well-drained soils on south- or west-facing aspects are typically chosen. These sites are where shortleaf pine naturally occurs. Hardwood and herbaceous weed competition is less intense on these sites following planting, and shortleaf pine is a more drought-tolerant species. Bareroot shortleaf pine seedlings are easily obtainable in Tennessee from the Tennessee Division of Forestry state nursery. Acceptable planting stock should average 10 to 12 inches tall with an average root collar diameter of approximately 3/16 of an inch (Conn 2012). Planting should be done as soon as possible after seedlings are acquired to avoid desiccation of the seedlings. They should be planted in late February or early March to avoid long periods of freezing temperatures that occur earlier in the winter season and to avoid planting in possible drought conditions that occur more regularly after this time (Mexal 1992). In addition, planting later than early or mid-March will reduce the growing season for seedlings during their first year and increase the chances of more undesirable vegetation occupying the site prior to planting (Barnett et al. 1986).

Planting holes should be made large enough so that root deformation such as J-rooting does not occur. Holes should not be too shallow exposing the basal crook. The taproot should be oriented vertically in the soil profile. Special attention should be given to these conditions to increase survival and growth after planting. Weeds and undesirable hardwoods should be controlled with fire and/or herbicides after planting to improve initial shortleaf pine growth and dominance.

Shortleaf Pine-Hardwood Mixtures

Historically, before the advent of fire control and the Smokey Bear campaigns in the 1950s, shortleaf pine-hardwood forests were abundant on average to poor productivity sites of the Cumberland Plateau, foothills and side slopes of the Blue Ridge Mountains, and the Piedmont region. These forests are defined as having pine basal areas of 25-75 percent per unit area (Sheffield et al. 1989). Frequent fires created seedbed conditions of bare mineral soil to allow successful seed germination, seedling growth and some control of understory and midstory vegetation. Shortleaf pine-hardwood forest types have transitioned to predominantly hardwood forests due to natural succession, southern pine beetle outbreaks, and the absence of fire, which is often necessary to naturally regenerate shortleaf pine. Many of the former mixed stands do not have a shortleaf pine seed source to perpetuate the species. Thus, to create these species mixtures, artificial regeneration of shortleaf pine is necessary.

Shortleaf pine-hardwood mixtures are attractive management options for landowners compared to other management practices such as pine plantations and pine savannas, which tend to have high establishment and maintenance costs and require large acreages to be feasible economically. Pine-hardwood mixtures offer landowners more species diversity and wildlife habitat options (Masters 2007) as well as wider markets for various forest products.

Pine-hardwood mixtures are a transitional forest type that eventually succeeds to longer-lived hardwoods (Cooper 1989, Halls and Homesley 1966, Olson and McAlpine 1973, Switzer et al. 1979). Without disturbance to allow the shorter-lived pine to re-establish in more open canopies, the pine will diminish. Shortleaf pine seed do not remain viable beyond one year. The disturbance, whether burning, harvesting or weather-related, has to be timed with a good seed-producing year, which occurs fairly infrequently. Good shortleaf seed crops occur every three to 10 years (Lawson 1990) and often do not coincide with the disturbance event. Thus, if exposed mineral soil and weather conditions are not favorable for seed germination when a good seed year occurs, the site often becomes overgrown and not receptive for seed in future years. The seed tree regeneration method for shortleaf pine often fails because favorable seed years and disturbances do not coincide.

Shortleaf pine is one of the few pine species with the ability to sprout from dormant buds located on a basal crook when the stem is killed (Guldin 1986). Burning will allow resprouting from the basal crook, which may give shortleaf pine a growth advantage and a survival mechanism compared to other species. However, most hardwoods also sprout and can compete with shortleaf pine. The tradeoffs between pine and hardwood establishment, growth and development in mixed stands, are poorly understood, even though these stands were widespread before fire suppression activities. Burning certainly had a role, but how burning impacted the mixed composition of these stands is not known.

Research, information and procedures for establishing shortleaf pine-hardwood stands are inadequate, especially when a shortleaf pine seed source is no longer available. Thus, specific guidelines or recommendations on mixed-stand establishment based on research as well as disturbance sequences that favor mixed stands are lacking. Mixed pine-hardwood stands comprised 2.2 million acres in Tennessee in 1950. Only 900,000 acres remained in 2009, and the acreage continues to decline (Oswalt and others 2012).

Sites that lack a nearby pine seed source will necessitate planting of shortleaf pine seedlings to establish pine-hardwood mixtures. There are several viable methods that can be implemented to establish this forest type, and selecting a method depends on finances and time invested as well as the desired pine component. All the methods covered in this section involve clearcutting the residual stand, which may not be an option for some landowners.

The first method is the **silvicultural clearcut** in which all merchantable timber is harvested followed by cutting/slashing of all remaining noncommercial stems taller than 6 feet. Shortleaf pine can then be planted the following year in late winter or early spring at wide spacings of 15 by 15 to 20 by 20 feet. The pines are planted at wide spacings to encourage the development of hardwood sprouts and seed germination in the openings between pine seedlings. This method is the most inexpensive to implement and involves the least amount of effort, but it will result in the lowest pine stocking per acre because the hardwood seed and sprout competition is not controlled.

Another method is the **fell-and-burn** site preparation technique. This method has proven effective in the Piedmont region of South Carolina for regenerating mixed shortleaf pine-hardwood stands and in the Ridge and Valley region of Tennessee for regenerating mixed loblolly pine-hardwood stands (Clabo and Clatterbuck 2015, Phillips and Abercrombie Jr. 1987). Fell-and-burn follows the same sequence of management activities as the silvicultural clearcut, but a broadcast burn is completed during late summer before pines are planted at wide spacings. The burn sets back hardwood seedling/sprout growth, initially allowing pine seedlings to establish and gain an early growth advantage. This method is less costly than establishing a pine plantation at 6 by 8 feet spacing using typical plantation site preparation treatments such as shearing, raking, piling, disking and aerial herbicide treatment(s) (Phillips and Abercrombie Jr. 1987).

The third method is the **brown-and-burn** treatment, which is initiated with a commercial clearcut followed by a broadcast herbicide application in late July or early August intended to reduce hardwood competition for a longer period than the fell-and-burn method. The herbicide application is followed by a broadcast burn in late summer. This method costs more than the fell-and-burn technique but results in greater pine stocking and less hardwood stocking.

Other variants for establishing pine-hardwood mixtures that have been tested include a silvicultural clearcut with a cut stump herbicide treatment of all hardwood stumps followed by an optional basal bark herbicide release of all hardwood stems within 3 feet of a planted pine seedling during the spring one year after the pine planting (Zedaker et al. 1989). The cut stump herbicide treatment and the basal bark release herbicide combination will favor planted pine. These methods may be very attractive to landowners who are hesitant to burn on their land. A disadvantage to stump-and-release treatments is the increased amount of manual labor required to implement the herbicide treatments.

If clearcutting is not an option for a landowner, a **two-age system** is a method being evaluated for introducing a shortleaf pine component into a stand. In hardwood-dominated stands, removing at least 50 percent of the mid and overstory basal area would be required to successfully grow planted shortleaf pine seedlings (Baker et al. 1996). Herbicide release treatments would be necessary on more productive sites to release the planted pine from the regenerating hardwoods. Cluster planting many seedlings in small group openings (1/10 acre or less) at tight spacings (5 by 5 feet or less) to return shortleaf pine to hardwood-dominated systems is another promising method that is currently being tested in the Cumberland Mountains of Tennessee. The anticipated structure is a two-cohort stand with a sparse, older overstory with naturally regenerating hardwoods and small clusters of planted pine. Overstory retention methods are less expensive than clearcut methods that involve more intensive site preparation and planting shortleaf pine at wide spacings over a larger land area, but the percent stocking of shortleaf pine will be less than with clearcut methods.

Other management scenarios are available with mixed pine-hardwood stands. One of the most common scenarios is to have a mixed stand where the pine could be harvested early to provide an intermediate income, leaving the hardwoods for longer rotations. However, the opposite could also take place, harvesting the hardwood for fiber markets and leaving the shortleaf pine for quality sawlogs or poles. Mixed-species management gives landowners options on marginal or cutover forest land that is presently poorly stocked or with degraded residual trees of limited value.

Shortleaf Pine Woodlands and Savannas

Woodlands and savannas are ecosystems with scattered fire-tolerant tree species in the overstory and grasses and herbaceous plants dispersed throughout the understory. Both of these ecosystem types are typically found on southern and western aspects on ridges and knolls where solar radiation levels are higher and fires burn hotter and more frequently. A woodland is defined as having 40 to 65 square feet basal area/acre, whereas a savanna has 10 to 35 square feet basal area/acre, but these are both loose definitions and may change with location (Burger and Keyser 2013). Establishment of woodlands and savannas in closed canopy forests combines the implementation of an initial timber harvest followed by a series of prescribed burns, leaving a sparse overstory and a regenerating understory of grasses, forbs and woody stems. Agroforestry involving livestock grazing is another feasible method that can be used to set back succession and maintain these systems.

Woodlands and savannas require periodic burning to set back succession, reduce the numbers of undesirable hardwood species such as red maple and yellow-poplar, and enhance herbaceous and grass vegetation. Thick-barked species such as shortleaf pine, oaks, persimmon and blackgum are common tree species found in woodlands and savannas in Tennessee. Typically, shortleaf pine must be present in the overstory prior to an establishment timber harvest or thinning in order to be present in a woodland or savanna. Immature shortleaf pine will resprout reliably after repeated burns in these systems and burning may encourage new seedlings due to exposure of bare mineral soil if mature trees are present in the overstory. In order for seedlings to grow large enough to reach the overstory and survive repeated prescribed burns, burning would need to cease at least three to five years on most sites, with average to above average rainfall years or for longer periods with more droughty years (Clabo 2014). Seedlings must avoid 60 to 70 percent or greater crown scorch in order to avoid topkill (Cain and Shelton 2002, Walker and Wiant 1966). Mature shortleaf pine is well-suited to these systems due to its fire tolerance and ability to prosper on droughty sites. Typically, shortleaf pine woodlands and savannas are viable options on larger acreages due to the smoke and fire escape risks that frequent burning can present. In addition, a timber harvest that removes only a portion of the basal area may not be profitable on smaller acreages.

Woodlands and savannas provide excellent habitat for game species such as white-tailed deer, turkey and northern bobwhite quail. Woodlands and savannas also provide habitat to uncommon or threatened bird species including red-cockaded woodpecker, red-headed woodpecker and Bachman's sparrow. Ample sunlight and frequency of disturbance allow native, pyrophytic (fire-dependent) warm-season grasses to prosper in woodlands and savannas. Common species include big bluestem, little bluestem, indiangrass, broomsedge, silver plumegrass, sideoats grama and poverty oatgrass. Many herbaceous plants are found more commonly in the open conditions of woodlands and savannas and include, but are not limited to, ticktrefoil, partridge pea, roundhead lespedeza, Illinois bundleflower, purple prairie clover, black-eyed susan, wild bergamot and goldenrod. The variety of wildlife and plant species found in savannas and woodlands makes them unique ecosystems, and the frequent disturbance conditions needed to perpetuate them are well-suited to the silvical characteristics of shortleaf pine.

Why Plant Pine?

Wayne K. Clatterbuck
Professor
UT Forestry, Wildlife and Fisheries

Planting pine can provide many ecological and economic benefits. Pine should be considered for reforestation following pine harvest or after southern pine beetle epidemics and for afforestation of marginal agricultural lands. Outlined below are a few factors illustrating why planting pine is an attractive alternative for forestation.

1. **Site Quality** – Most pines occur on marginal sites that are better suited for pine (both ecologically and economically) than hardwood. These sites are often low in nutrients required for hardwood growth or agricultural crops. Hardwoods are more site-demanding than pines. Although various hardwoods will survive on these sites, they are not as prosperous, will not grow as fast, and will not produce the "quality" hardwood sawtimber that brings the most income. Hardwoods are more sensitive to weather fluctuations, particularly the late summer droughts that frequently occur on these shallow, dry soils. Pine will produce a product on these marginal soils in a shorter time period than hardwoods. On low-productivity upland sites, those of shallow soils and south- to west-facing slopes, favoring pine over low-quality hardwood species should be considered.

   Pines will grow on the better sites, too, but the cost of establishment and control of hardwood competition can be excessive. However, the shorter rotations of pine compared to the longer rotations for hardwoods may compensate for these costs. The production of pine volume on these sites is often greater than that produced on the ridges.

2. **Ease of Planting and Seedling Cost** – Pine seedlings are cheaper and easier to plant than hardwoods. Seedling costs for pine average $80 to $100 per 1,000 seedlings, while hardwoods such as yellow-poplar and oaks average $350 or more per 1,000 seedlings.

3. **Economics and Returns** – Pine is more valuable on the timber market than the red maple, low-grade oaks and sweetgum that generally occur on poorer sites. Pines are more inexpensive to establish and are grown at shorter rotations (20 to 35 years) than hardwoods. Establishment and management costs are recovered more quickly with the shorter rotations. The annual rate of return for pine in Tennessee averages 8 to 12 percent per year. Refer to UT Extension publications PB 1462 and PB 1466 for typical financial analyses for growing pines (extension.tennessee.edu/publications/Documents/PB1462.pdf and extension.tennessee.edu/publications/Documents/PB1466.pdf).

4. **Risk to Southern Pine Beetle Attack** – There is a good chance that at some time during your pine rotation southern pine beetles (SPB) will appear. They are a native pest, are always present, and tend to build to outbreak population levels every eight to 10 years. Our skills as pine managers will be tested to monitor, manage and capture the value of these trees before potential losses to SPB occur. The key is to manage these stands so that they remain healthy, vigorous and less susceptible to SPB.

   Hardwoods are also susceptible to damaging agents such as insects (defoliators, borers and piercing/sucking organisms) or diseases (cankers, wilts, root rots and other decays) as well as unfavorable climatic variations, primarily droughts. The risk of growing hardwoods may even be greater considering their longer lifespans when compared to pine. Risk is always present when growing tree crops, and managers should monitor their property frequently to minimize potential losses and promote healthy trees through their management activities.

5. **Ecology** – Most pines are shade-intolerant, requiring full sunlight to grow. They will not survive long in the shade. Pines are known as "pioneer" species, regenerating naturally on disturbed sites with their wind-blown seed. Pines have been part of the Tennessee landscape for many years, colonizing old fields and disturbed areas. Sudworth and Killebrew discussed the abundance of pine in Middle and East Tennessee during presentations at

the American Forestry Association meeting in Nashville in 1897. While the amount of shortleaf, pitch and Table Mountain pine has decreased and the amount of loblolly pine has correspondingly increased, the total amount of pine in Tennessee has remained steady at 1.1 to 1.5 million acres since 1950 (USDA Forest Service, Forest Inventory Analysis (FIA) Tennessee Data, 1955, 1962, 1971, 1982, 1990, 2000, 2004, 2009, 2012).

6. **Planting vs. Natural Regeneration** – Pines can readily regenerate naturally from seed, if exposed to mineral soils and full sunlight. So why is there interest in planting pine seedlings?

    a. Planting pine provides more control over stand density (spacing) and arrangement. With natural seed fall, wherever a seed falls and germinates is where a new tree begins to grow. Natural stands are often too sparse or too dense, leading to added expense later (precommercial thinning) or incomplete utilization of the site. Planting gives more control of growing space and decreases the risk of establishing a pine stand that is too dense or too sparse.

    b. Pine has a shorter establishment period. Good seed crops do not occur every year, so the site could be idle for several years before adequate regeneration takes place, thus creating problems with undesirable vegetation. Also, planting may reduce the length of rotation and increase the rate of return on investment.

    c. An adjacent seed source may not be available for natural regeneration of pine. Planting is necessary to establish pines.

    d. Pines have been developed through tree improvement programs that have better form, faster growth and more resistance to insects and disease. Planting, as opposed to natural regeneration, allows using seed from improved sources.

    e. Planting does involve the costs of seedlings, planting, site preparation and control of undesirable vegetation, if needed. However, in most cases, these costs are compensated by the improved growth of planted trees at proper spacings.

7. **Species** – Several pine species are available for planting in Tennessee. Each species has its advantages and disadvantages. The species selected will depend on the site, management objectives, product objectives and costs.

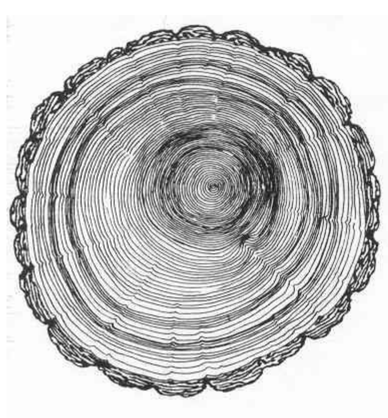
    a. <u>Shortleaf pine</u>: Long-lived tree with dense wood and straight form. Shortleaf is less susceptible to ice damage than loblolly and white pine but grows slowly and is susceptible to SPB. The market for shortleaf is primarily sawlogs, which require longer rotation lengths. Seedlings are sometimes difficult to find. Shortleaf pine has the ability to sprout which may aid in its regeneration.

    b. <u>Loblolly pine</u>: Fast growth, widely available, inexpensive seedlings. Usually grown at shorter rotations for pulpwood or sawlogs. Loblolly pine is particularly susceptible to ice storm breakage when young and to SPB. Loblolly grows on a variety of sites — a “generalist.”

    c. <u>Eastern white pine</u>: Fast growth and less susceptible to SPB than shortleaf and loblolly. Markets are limited and the species is very site-specific. White pine will tolerate some shade as a seedling, but will eventually die unless released to full sunlight. Usually grows best at cooler temperatures at the higher elevations. White pine performs best from the Cumberland Plateau eastward in Tennessee. The tree will not tolerate excessive heat and droughts. Seedlings are the most expensive of the pines because they are grown for two years in the nursery before outplanting when most other pines are grown for one year.

8. **Diversify Your Forest and Forest Investment** – A tremendous benefit of planting pine is that early successional habitat and winter cover are created for wildlife. Pine offers many attributes for wildlife that cannot be satisfied entirely by hardwood forests.

Pine provides more frequent income intervals than hardwoods. Considering that the rotation length for most managed hardwoods is 40 to 80 years, the income flow from pine is at a much shorter interval. Diversification of your forest and your forest investment can be provided in two ways by planting pine. First, pine plantations can be established among hardwood tracts. Second, a mixed pine-hardwood planting will provide income flows from pine in the short term, leaving hardwoods for the long term.



Planning a Planting Project

David Mercker
Extension Specialist
UT Forestry, Wildlife and Fisheries

Planning the steps to a tree-planting project should follow a sensible chronological order. Doing so will ensure success. Adequate lead time is essential, beginning at least one year prior to the anticipated planting date. It is a building process, one that begins with establishing your personal land management goals and, through a series of steps, is brought to fruition through perseverance.

The following is a checklist for planning your tree-planting project:

1. Seek professional forestry assistance.

Professional foresters from the Tennessee Department of Agriculture Forestry Division (TDA-FD) are available for technical forestry assistance. Serving as your point of initial contact, they can advise you about the steps needed for a successful planting. To locate your local area forester, contact the TDA-FD state office in Nashville at 615-837-5520 or online at www.state.tn.us/agriculture/forestry/directory.shtml.

Professionals can use their expertise to evaluate your local conditions (site productivity, competition, etc.) and prescribe several options, each with advantages and disadvantages, to address your management goals. Then you can choose the prescription that best fits your management objectives and finances.

Additional limited service is available through the Tennessee Wildlife Resources Agency, the county offices of University of Tennessee Extension and the Natural Resource Conservation Service. Consulting foresters or industry foresters are also worth contacting, and are often the ones who implement forestry projects.

2. Develop a forest-management/tree-planting plan.

Forest management is an involved process, one that is best simplified and organized with an action plan. A plan serves as a guide, clearly establishing your management goals, and then outlining steps needed to successfully achieve those goals.

A tree planting plan can stand alone or can be integrated into a more comprehensive plan that includes the entire forest and wildlife habitat on your property. A comprehensive plan includes components that address timber stand inventory, intermediate stand management, harvesting the forest, wildlife habitat enhancement, protection measures for water/soil resources, recreation, aesthetics and much more.

Your tree-planting plan should include these components:

- Ownership goals and objectives;
- Location and maps of the property and planting site;
- Site analysis (soil characteristics, natural features of the land, climatic patterns and biotic factors such as existing vegetation/wildlife/insects, etc.);
- Site preparation steps;
- Planting scheme (species to plant, spacing, seedling age, planting method);
- Dates or timetable for implementation;
- Seedling care prior to and during planting;
- Control of woody and herbaceous vegetation;
- Cost-share and tax considerations

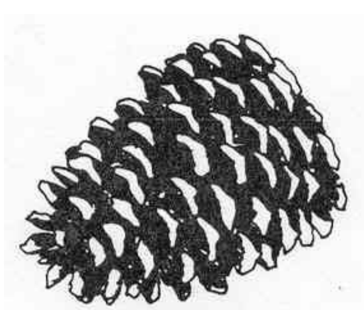
3. **Secure cost-share funding.**
   Cost-share funds from both federal and state governments are normally available to offset expenses associated with investments in tree planting. Examples of these programs include the Conservation Reserve Program (CRP) and the Wildlife Habitat Incentive Program (WHIP).

   Your professional resource manager can assist you in securing cost-share when available. In most cases, cost-share must be pre-approved in advance of implementing the project. Further, some forest industries have forest management assistance programs that can include reduced seedling cost and management assistance.

4. **Order seedlings.**
   Demand for seedlings is normally high. To ensure your supply, order seedlings six to nine months in advance of the anticipated planting date. Seedlings are available through TDA-FD and from private nurseries. Lists of private nurseries can be obtained by contacting either your local area forester or University of Tennessee Extension director for your county.

5. **Hire a planting contractor.**
   Unless you intend to plant the seedlings yourself, an independent contractor will be needed to administer the project. Normally, contractors are better equipped and have personnel trained to care for your seedlings and plant them properly at the appropriate time. A separate contractor may be needed for extensive site preparation such as prescribed burning or herbicide application. Check their references, obtain copies of their insurance certificates, and use a thorough contract for your and their protection.

Remember, it is better not to have planted your land than to have planted incorrectly. Having a planting plan established will help secure your investment in your land.



Planting Pines

David Mercker
Extension Specialist
UT Forestry, Wildlife and Fisheries

Tree seedlings receive foremost care while growing in a managed nursery: fertile soil, ample moisture and weed/insect/disease control. Lifting seedlings out of this comfort zone shocks them. Consider this: Soil is dislodged from their roots, they are handled several times, packaged, shipped, exposed to threatening wind and heat, placed in planting bags or machine buckets, roots unveiled to open air, replanted in often very harsh soil, then left to high temperatures in the hope of adequate precipitation for sustenance through the first few growing seasons.

If planting steps are not followed carefully, mortality rates rise. Seedling survival is more likely if attention is given to the following steps:

1. **Plant in late fall or early winter.**
   In Tennessee, December, January and February are ideal months for planting seedlings. Tree roots grow during cooler months. By planting well before the growing season, roots will settle into their new environment, elongate and begin preparing to supply water to the foliage when warmer temperatures arrive.

2. **Plant on cooler days.**
   Temperatures ranging from 35-55 F are ideal. Higher temperatures could cause transpiration rates to increase and dry the roots. Transpiration is the process by which water vapor leaves a living plant and enters the atmosphere. Lower temperatures could freeze the roots, causing mortality.

3. **Protect seedlings during vehicular transport.**
   Transporting seedlings in an enclosed vehicle is preferred to open-air transport. If open air must be used, cover the bags of seedlings with a tarp. High winds increase transpiration rates, rapidly drying the roots. It is best to transport on cool days or at cooler times of the day.

4. **Proper seedling storage.**
   Seedlings will remain healthier if they are stored in an enclosed cooler where temperature and moisture are regulated. Keeping the air temperature low and humidity high will slow transpiration. Maintain air temperature at 35-38 F.

   Find a place to store your seedlings well ahead of their arrival from the nursery. When stacking bags of seedlings for long storage, crisscross them, leaving large air gaps for better ventilation. Otherwise, heat will build near the center of the bags, causing seedling mortality.

   If controlled facilities are not available, or if the seedlings will be planted quickly in the field, store the seedlings in a cool, dark location, away from wind. Periodically inspect the roots and needles to determine if watering is necessary.

5. **Seedling treatment at the planting site.**
   Once on-site, seedlings can deteriorate rapidly. High air temperature and wind place stress on seedlings. Park your transport vehicles in the shade, in lower spots, shielding the seedlings from destructive elements. Insulation tarps provide desirable protection. Avoid opening seedling bags until close to the time of planting. Avoid exposing roots to the open air for very long. If air temperature reaches 75 F, planting should cease. Large portable coolers are ideal for storing seedlings in the field.

6. **Methods of planting.**

Two methods are used for planting tree seedlings: hand planting and machine planting. Both are acceptable.

Hand planting is more common on steeper terrain or in forested areas that have been harvested recently. Hand tools are used to penetrate the soil and create an opening for the roots. Once the seedling is planted, the hole is resealed with the tool and foot pressure.

A machine planter is normally pulled behind motorized equipment with a 3-point hitch. The planter has a coulter to slice through the soil, a foot to pull the machine below surface level, trencher plates for opening the soil for seedling placement, and packing wheels to re-close and compress the soil. Machine planting as compared to hand planting generally has slightly better survival rates, delivers more consistency in spacing, and works best when converting old fields to forest.

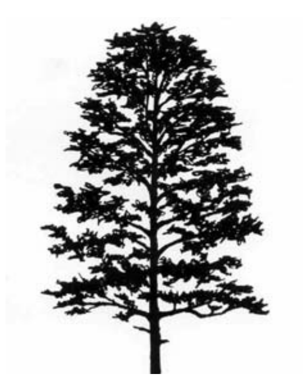
Care should be taken not to "J-root" seedlings, but rather leave the root in a natural, vertical position. Plant seedlings deep, at least to the original level planted while in the nursery, as noted by the darkened ring where the lower stem meets the roots. It is better to plant slightly too deep than too shallow. Make sure that all air pockets are sealed by applying pressure to the soil surrounding the seedling. Straighten seedlings as needed.

7. **Conduct a survival check.**

For the first two summers after planting, conduct a survival check. If cost-share funds were used to establish the planting, it may be necessary to maintain a certain level of live seedlings. The original planting plan should have specified this minimum survival level. Your forester can assist with your survival check.

Spacing for Planting

There is no magic spacing to produce the best results when planting your seedlings. Landowner objectives, markets and level of involvement will help dictate the number of trees per acre that should be planted. Planting density should be guided by the productivity capacity of the site, as well. Planting at initially high stocking levels will result in a stand that reaches canopy closure quicker than a stand with low stocking levels. The denser stand may produce taller stems as individuals compete for sunlight earlier in stand development. A wider spacing limits the competition between trees but also can result in "bushy" or expanded crowns. Landowners should find a level of stocking that will meet their objectives. The denser the stand, the earlier a thinning will be required to promote continued growth and stand health. Otherwise, the closely planted trees will stagnate and decline, making them more susceptible to southern pine beetle attack. A stand planted on 5 feet by 5 feet spacing would have 1,740 seedlings per acre, while stands planted on 10 feet by 10 feet spacing would initially have 435 seedlings per acre. In areas that are susceptible to southern pine beetle, a spacing of 8 feet by 10 feet or 10 feet by 10 feet (435 to 600 trees/acre) is recommended to maintain healthy, vigorously growing trees.



TIMELINE OF PINE PLANTING

YEAR 0:

Harvesting of
original stand

Site Preparation
Mechanical

Fire

Herbicides

Herbicides

YEAR 1:

Planting the site

YEARS 2 THROUGH 5:

Release (post-event pictured)

Natural Regeneration

YEARS 12 THROUGH 18:

Thinning

Prescribed fire for wildlife objectives

A MATURE SAWTIMBER PINE STAND READY FOR HARVEST

Photographs were supplied by Wayne Clatterbuck and www.forestryimages.org

WHY PLANT PINE?

1. Better suited for marginal sites than hardwoods.
2. Easier and less costly to plant than hardwoods.
3. Shorter rotations are more economically attractive than long hardwood rotations.
4. Planting gives more control over spacing and shortens the establishment period.
5. Planting allows for the use of improved genetic stock.
6. Several species of pine with varying benefits are available for planting in Tennessee.

Site Preparation

Daniel Cassidy
National Program Manager, Bioenergy
USDA, National Institute of Food and Agriculture (NIFA)

The most critical time in the life of any stand is just before and during the establishment of regeneration. This period often defines the future composition and productivity of the stand. To actively mitigate conditions to favor landowner objectives, techniques classified as site preparation are often applied prior to the establishment of seedlings, either through seed (natural regeneration) or planting (artificial regeneration). Foresters use site preparation to control competition on the site, prepare the site for planting by removing brush and litter, and prepare the planting beds for seedling establishment.

Three classifications of site preparation are chemical, mechanical and burning. All three can be used effectively in any combination given the economic constraints of the landowner. Cost-share programs may also be available to help offset the costs of these early operations.

Chemical Site Preparation

Site preparation that uses the systematic application of herbicides is classified as chemical site preparation treatment. The goal of the process is to control dense or unwanted vegetation that might interfere with the survival and development of seedlings. The application of the herbicide can also inhibit competing hardwood sprout competition. Pines are typically shade-intolerant and flourish when direct sunlight is available. The removal of overtopping vegetation increases the survival of planted seedlings. Herbicides leave a lighter footprint on the site compared to mechanical site preparation. The soil is not physically altered through disking or compaction, and the risk of erosion is minimal.

Herbicides can be applied through aerial application from a fixed-wing aircraft, from a boom sprayer attached to a helicopter or, in areas where this is not economically or physically possible, herbicides can be applied on the ground. Broadcast spraying from backpacks and tractors are common methods as are direct stem injections of the herbicide through either “hack and squirt” applications using an ax or basal sprays applied to individual stems and stumps. On-the-ground applications are often more time-intensive and expensive than aerial spraying but are better suited for smaller areas, stands with sparse competition, or in stands where only spot treatment is desired.

A professional forester should be contacted prior to using any herbicide to protect water quality and to make sure that all laws and regulations are followed.

Mechanical Site Preparation

Mechanical site preparation works toward removing unwanted vegetation or breaking down logging slash and debris. These techniques are accomplished by using heavy tractors and bulldozers to pile, rake, shear or disk the woody debris and vegetation. By moving the material, foresters are able to prepare a clean planting bed, reduce standing competition, and often till or mix the soil and the organic material to enrich the soils and increase productivity.

Just like many herbicides that can be used in chemical applications, there are many mechanical techniques available, ranging from simply knocking over stand vegetation to pushing the debris into organized piles or windrows.

Mechanical preparation is often used in conjunction with fire, burning the debris once it has been piled together. Mechanical operations are more common than aerial spraying and may be part of the logging contract. Mechanical site preparation should not be applied on sites with severe slopes or easily erodible soils. Chances of erosion are increased with mechanical site preparation, because soil is dislodged. Use of best management practices and streamside management zones is essential when applying mechanical site preparation methods. Working with a professional forester will assist in deciding how intense the operation should be and the best mechanical application to use.

Fire in Site Preparation

Fire reduces the levels of slash, debris and litter, while exposing mineral soil and organic matter. A properly timed fire will delay or hinder vegetation that initially invades a harvested stand and will also increase the ease of planting seedlings.

Controlled fire should be used only under ideal conditions. If the site is too wet, the application will be useless. If the site is too dry or wind and weather conditions are not ideal, the fire can burn too hot and create potential short-term nutrient and erosion problems in the area to be planted.

Smoke management should be a priority when applying fire. Considering the liability and safety issues surrounding the application of fire, landowners should always work with a professional forester and double check to ensure that all the proper permits and regulations have been filed and followed.

Research has shown that the better a site is prepared, the more likely a release treatment will not be needed two or three years later. Investments made prior to the establishment of the stand will result in higher returns when the harvest is conducted.

Herbicides and Pine Release

Fitzroy D. Bullock
Extension Professor
Tennessee State University

Herbicides for vegetation control in forestry are well-established. The development of more cost-effective herbicides and application equipment has led to the increased use of this forest management tool. Economic studies show that significant growth and improved survival are possible when woody and herbaceous competition is controlled.

Herbicide Use

Herbicides are used in many ways:

1. Release of newly established seedlings,
2. Woody release of young trees,
3. Site preparation to establish a new stand of trees, and
4. Mid-rotation hardwood control after an initial thinning.

Most cut-over areas or new sites require some type of site preparation and/or release for successful tree establishment. Vegetation control can also be of value when maintaining natural stands of pines or pine-hardwood mixtures. When pines are planted on old-field or new sites, herbaceous weeds can retard growth significantly and reduce pine survival. In many situations, controlling competing vegetation can be done best with herbicides where mechanical control is not possible.

What Are Herbicides?

Herbicides are chemicals that suppress or kill certain plant growth. They affect plants by disrupting some internal growth or development function. Most herbicides do not affect humans and animals when used properly, since our growth and development is different from that of plants. Thus, forest herbicides are considered safe when specific label directions are followed.

Care must be taken when handling concentrated herbicides to protect eyes, internal tissue and skin. Many herbicides are formulated in common petroleum or alcohol-type carriers that may cause severe irritation or tissue damage. At a minimum, wear a long-sleeve shirt, long pants, plastic or neoprene gloves and some type of eye protection. Follow specific label requirements for protective clothing and equipment that may be required.

Herbicides registered for forestry uses by the United States Environmental Protection Agency (EPA) and Tennessee Department of Agriculture, Pesticide Division, have been well-tested. More than one herbicide and application method may be registered for use on the same site. Choose the herbicide or combination that will most effectively and economically control the targeted plants. Applying an herbicide not registered, or for uses not indicated on the label, is illegal and may cause adverse effects to nontargeted species or the environment. Always read the label before using any herbicide. Copies of the label(s) and the "Material Safety Data Sheet(s)" (MSDS) are available online and from suppliers and manufacturers. Also obtain information on endangered species in your area, for there may be restrictions on the use of certain materials. Before the herbicide application, read and carefully follow the information on the label and the MSDS for a safe, effective herbicide application.

The laws require that applicators be certified before they can purchase or apply "restricted use" pesticides, but it is suggested that applicators of any pesticide be certified. The certification process will add to your knowledge about herbicide safety and attest to your competency.

Applicators for hire must be certified by the Tennessee Department of Agriculture before they use any pesticide. They must have a pesticide contractor's license and sufficient liability insurance. Contact the Tennessee Department of Agriculture for further information.

Forest Weeds

Forest weeds are unwanted vegetation that compete or interfere with timber and other resource management objectives. The weeds can be obstacles to regeneration, crop development and growth as they compete for moisture, nutrients and light. They may be classified as weed trees, brush, vines and herbaceous weeds (broadleaf weeds and grasses). The following section addresses weed control as it relates to specific sites.

Site Evaluation

1. **Soil Type**: Soil type influences the effective performance of a herbicide. If the soil is high in clay, a higher rate of a herbicide (within the recommended rate range) is more effective, because herbicides have a tendency to be readily adsorbed or tied up by clay particles, making the herbicide less available for weed kill. Herbicides applied to clay soils will not leach or volatilize. If the soil is high in sand, a lower rate of a herbicide (within the recommended rate range) is more effective. Because herbicides applied to sandy soils are not readily tied up, they will kill the weeds effectively. However, herbicides applied to sandy soils can be leached and volatilized easily, making long-term weed control more difficult.

2. **Weed Species**: Since susceptibility of plants to herbicides is an important factor in good weed control, the weed species must be identified properly to allow the selection and application of an effective herbicide. If the weed species is not on the herbicide label, the weeds may not be killed.

3. **Pine Species**: There are several pine species, so it is important that the herbicide you use is recommended for the pine species you have planted. Some pine species have good tolerance to a herbicide, while others will not tolerate the herbicide toxicity.

4. **Climatic Conditions**: Climatic conditions, such as rainfall and temperatures, are critical to the performance of a herbicide. Under normal conditions, adequate moisture and warm temperatures will allow better herbicide uptake and foliar absorption, resulting in better weed kill. If temperatures are too cool (below 50 F), herbicide uptake by roots and leaves will be reduced greatly. If soil moisture is limited (<40 to 50 percent of field capacity), plants are stressed, causing poor herbicide uptake.

5. **Herbicide Selection**: A limited number of herbicides are registered for use in newly planted pines. The selection of a herbicide must be based on the weeds present or expected. If the herbicide has only pre-emergence activity, it must be applied to the soil before weeds begin to emerge. If the herbicide has both pre-emergence and post-emergence activity, it may be applied after weeds emerge but before they get too large (generally not more than 2 to 4 inches tall). If the herbicide has only post-emergence activity, it must be applied after the weeds emerge but before they get too large.

6. **Herbicide Application**: If the application and equipment calibration is not completed correctly, the treatment will not achieve maximum performance. Therefore, it is important to use the correct volume and pressure and appropriate equipment. If a band treatment is used, the bandwidth should correspond to the weed species. If the weed species present are of the low-growing type, such as grasses (except Bermuda), a 3- to 4-foot band is adequate. If weed species are of the tall-growing type, a 5- to 6-foot band is recommended.

Herbicides can be applied in a variety of ways. Some applicators work on the ground, spreading the herbicide using backpack sprayers or tractor-mounted mist-blowers. Other methods are more physically demanding, using a “hack-and-squirt” method that depends on injecting the tree using a hydro-hatchet or a spray bottle. Herbicides can also safely be applied aerially from a helicopter. New advances in technology have improved application techniques greatly. GPS units monitor the exact placement of the applications, and a wide range of nozzle gauges effectively govern the application rates.

Pine Release

The establishment of a new pine stand involves control of competing trees, shrubs and vines. The control of less desirable vegetation is accomplished through the herbicide release of 2- to 5-year-old pine seedlings or from site preparation prior to planting or both. Herbicides are also used for mid-rotation hardwood control after the first thinning. This application improves pine development and wildlife habitat.

Herbicide Labels and Selection

Appropriate application methods are specified on herbicide labels. Currently labeled herbicides and their recommended rates are updated each year. Additional information is available at your county Extension office or chemical dealer.

This information should help you understand the requirements for an effective, economical and safe vegetation control operation. Various herbicides are registered for use in planted pines. These herbicides or herbicide combinations will not give 100 percent control of all weed species, but if treatments are properly applied and conditions are favorable, adequate control will be obtained. The timing of herbicide applications is critical to obtain the best results. Several guides are available online that list herbicides for weed control in pines. One that is updated frequently is from the University of Georgia (www.bugwood.org/weeds/ForestHerbicides_Moorhead2015July.pdf).

Precautionary Statement

To protect people and the environment, herbicides should be used safely. This is everyone's responsibility, especially the user. Read and follow label directions carefully before you buy, mix, apply, store or dispose of a herbicide. According to laws regulating herbicides, they must be used only as directed by the label.

Thinning Pine Stands

Wayne K. Clatterbuck
Professor
UT Forestry, Wildlife and Fisheries

Thousands of pine seedlings populate a naturally-seeded acre. In a plantation, usually 500 to 800 seedlings are planted. As pine stands grow and mature, individual trees compete for light, soil moisture, nutrients and space. Many trees are crowded by faster-growing neighbors and die so that at maturity only 50 to 100 large-diameter sawtimber (greater than 18 inches in diameter) pine trees per acre remain. More than 90 percent of the trees succumb. This mortality is a natural progressive process in the forest. As trees grow larger over time, the amount of space and resources becomes more limited and reduces the number of survivors in the stand.

Thinning is a forestry technique that mimics this natural process of mortality under the guidance of a trained professional. By applying cuts to immature stands, material that might otherwise die before rotation age can be used and growth can be concentrated on fewer, more desirable stems left in the stand. Thinning improves the conditions within the residual stand by providing increased growing space and availability of sunlight for individual trees. The increased growth, vigor and space available to these trees produce a healthier stand. The residual or remaining trees may be selected to meet any landowner objective such as wildlife, timber, recreation or aesthetics, but the result will ultimately reduce the time required for trees to reach a target diameter class. The decreased rotation length shortens the period of return on the landowner's investment. If markets are available, some intermediate returns are possible from the thinned material removed.

When to Thin?

While there is no "magic" number of years to wait until applying a thinning, several indicators suggest when thinning should occur. As trees grow and mature, their crowns will begin to compete for available sunlight. Eventually this crown competition will result in a forest with a closed canopy, where sunlight does not reach the forest floor. This indicates that the tree crowns no longer have space to grow and expand. Tree growth declines and stagnates, and tree health is impaired. A thinning should be applied. A more quantifiable estimate of when to thin based on crown structure is when live crown ratios are less than 33 percent. The live crown ratio is the length of the crown divided by the total height of the tree. Live crown ratios decrease because sunlight is not getting to the lower branches, decreasing the photosynthetic area of the tree and resulting in mortality of lower branches.

Basal area per acre is another good estimate of when to thin. Basal area is a measure of stand stocking. It is the sum of the surface area in square feet taken by an individual tree trunk at 4.5 feet for all the individuals growing on an acre. As basal area exceeds 120 square feet per acre, individual tree growth declines, and the stand becomes unhealthy. For most pine stands, a thinning that results in 70 to 90 square feet of residual basal area per acre represents an ideal stocking rate. A 14-inch tree is approximately 1 square foot of basal area.

What to Thin?

Which trees to remove will depend upon landowner objectives. For timber production, undesirable species, poor-formed trees and slow-growing individuals are removed. Wildlife considerations may leave some of the poor-formed or cull trees to provide habitat. How much to thin will depend on objectives as well, but it must be enough trees for loggers to make a profit. A common mistake in thinning is to leave too many trees in the residual stand. Generally, 40 to 60 percent of the trees are harvested during a thinning. Several thinnings may take place before the stand reaches maturity. At final harvest, when pine trees have reached sawtimber size, usually 80 to 100 trees per acre remain.

How to Thin?

Depending on when the stand is thinned, the cut can be deemed either a precommercial or commercial thin.

Precommercial thins are generally required in stands that are naturally regenerated, where thousands of seedlings per acre are established. The goal of a precommercial thin is to reduce stocking to 400 to 600 stems per acre. There is no merchantable material removed during this thinning; thus, it occurs at an expense. However, the removal of the excess trees will prevent stagnation and improve stand growth and development. To minimize cost, precommercial thinnings should be conducted when the stand is 4 to 6 years old. Mowing strips across the stand, leaving seedlings in 1- to 2-foot-wide rows, will quickly reduce the total number of seedlings. Row width is dependent upon seedling density.

Commercial thinnings occur typically when the stand is 12 to 18 years of age and can provide some intermediate return on long-term forest investments. There are traditionally two methods of commercial thinning: row and crown class. A row thinning is the easiest thinning method to apply. With little regard to crown class, rows of pines are selected and removed, providing additional growing space for trees in the leave rows. This method is easy to mark and to implement.

A crown class thinning requires a more acute eye. Crown class thinnings favor only the best trees by removing the inferior individuals and producing a consistent spacing around the leave trees. This allows the favored leave trees to use the additional growing space and mature into the desired product size. The removal of the smaller, inferior trees may or may not produce an immediate economic return from the cut.

Summary of Thinning

Mortality is an inescapable function of nature. By actively managing pine stands, this mortality can be reduced by allowing select individuals to take advantage of additional space, sunlight, moisture and nutrients. The fundamental results from thinning are the improvement of stand health and growth and a reduction in the rotation length. Many pine stands devastated by the southern pine beetle outbreaks were overstocked, stressed and growing poorly. A properly timed thinning will help prevent that situation from occurring.

Shortleaf Pine Growth and Yield

David Clabo
Graduate Research Associate
UT Forestry, Wildlife and Fisheries

Shortleaf pine is a suitable species for plantation plantings, especially in areas north of loblolly pine's range. Shortleaf pine should be considered for plantations when sawtimber is the desired timber product. Loblolly pine is usually planted when pulpwood or biomass are the desired timber products because of its faster growth rates on most sites in Tennessee up until about ages 40 to 50. Mortality occurs more often in loblolly pine because its greater growth leads to more crowding and competition than shortleaf pine. Basal area and cubic foot volume increase more quickly in loblolly pine while mean annual basal area increment and mean annual volume increment decrease more quickly with age than for shortleaf pine. The more consistent growth of shortleaf pine makes it more suitable for longer sawtimber rotations (Smalley 1979). Growth and yield summaries comparing shortleaf and loblolly pine plantations on similar sites in Tennessee, Alabama and Georgia are presented in Table 2. *Growth and yield of loblolly and shortleaf pine are very similar according to these references for the investigated sites!* However, for greater productivity Coastal Plain sites in West Tennessee, loblolly pine may outperform shortleaf pine. Shortleaf pine planted for sawtimber rotations should be planted at 8 by 8 feet to 10 by 10 feet spacings if high-quality seedlings are planted to reduce the need for precommercial thinning (Barnett et al. 1986).

Growth and yield of shortleaf pine in Tennessee is one of the least studied areas concerning this species, but some information is available for unthinned stands on old field sites. Smalley and Bailey (1974b) developed schedules for trees per acre, basal area, mean tree height and cubic foot yields for shortleaf pine plantations planted at a variety of spacings and site productivities throughout the Cumberland Plateau, Eastern Highland Rim and Western Highland Rim physiographic regions of Tennessee. They reported that survival percentage decreases as planting density and age increase. On better sites, survival is greater at early ages and lower at older ages because of increased hardwood competition. They also observed that sawlog-sized trees could be produced in 25 years on good sites (site index 60 feet at base age 25 years) even at dense (4 by 5 feet) spacing. Total and merchantable cubic-foot volume yields per acre increased from age 10 to 40 for each site index and spacing, except by age 35 and site index 60 when yield began to level off, especially at higher planting densities (Smalley 1986). The highest yields were at age 20 on site index 60 sites when total cubic volume increased at a rate of about 11 ft^3/acre/year or 135 board feet/acre/year.

Thinning studies of shortleaf pine in Tennessee are nonexistent, and the most analogous sites to those in Tennessee were shortleaf pine plantation thinnings in southern Indiana and Illinois. In the Indiana study, shortleaf pine was planted at 6 by 6 feet spacing on productive sites (site index 80 feet at base age 50 years). Results suggest that free thinning before age 30 would have little effect on growth and yield (Phipps 1973). At wider plantation spacing, longer periods until the first thinning would be likely on these sites. The studies from southern Illinois indicate that the first thinning should probably not be delayed past 25 years on moderate and good sites at 6 by 6 feet spacing or live crown ratios will become too low for trees to respond to thinning. On poor sites, thinning should be delayed up to 10 years until diameters are large enough to become merchantable for pulpwood (Burkhart and Gilmore 1967). Crown thinning has generally proved to be the preferred thinning technique for improving the number and quality of sawlogs in shortleaf pine plantations (Smalley 1986).

Table 2. Shortleaf and loblolly pine yields for plantations in Tennessee, Alabama and Georgia growing on site index 60 (base age 50 years) productivity sites at a planting density of 1,250 trees/acre. O.B. is diameter outside bark and I.B. is diameter inside bark. Table adapted from Smalley and Bailey (1974a and 1974b).

Age	Mean Diameter	Total Stems	Basal Area	Mean Height	Total Volume		Total Volume per Tree[a]	Volume/Acre of All Trees > 5 inches dbh to a 4-inch Top O.B.	
					O.B.	I.B.		O.B.	I.B.
yrs	*inches*	*#/acre*	*ft^2/acre*	*feet*	*----ft^3/acre---*		*(board ft)*	*--------ft^3/acre--------*	
Shortleaf Pine									
10	4.2	1108	106.8	24	1388	961	15	484	291
15	5.3	1032	158.8	37	3039	2169	35	2072	1466
20	6.1	907	164.4	47	4490	3215	59	3662	2711
25	6.8	759	192.8	55	5486	3934	87	4827	3637
30	7.5	609	189	61	6019	4320	119	5509	4171
35	8.4	471	181.1	67	6259	4494	159	5873	4429
40	9.4	354	170.7	73	6446	4629	218	6157	4605
Loblolly Pine									
10	4.4	1061	113.4	29	1697	1229	19	774	520
15	5.6	978	167.5	40	3434	2494	42	2576	1893
20	6.4	860	194.9	49	4858	3532	68	4115	3109
25	7.2	728	204.8	56	5796	4217	96	5145	3940
30	7.9	596	202.1	63	6418	4667	129	5843	4511
35	8.6	476	193.4	68	6629	4821	167	6130	4740
40	9.5	371	162.2	72	6523	4745	211	6093	4705

[a] Conversion is 12 board feet = 1 cubic foot

Pests and Diseases of Shortleaf Pine

David Clabo
Graduate Research Associate
UT Forestry, Wildlife and Fisheries

Most of the pests and diseases discussed for shortleaf pine are also applicable for other southern yellow pines: Loblolly, Virginia, pitch and table mountain. The exception is white pine weevil that occurs exclusively on eastern white pine.

Shortleaf pine does not have many serious insect and disease pathogen concerns compared to other southern pine species if regenerated on suitable sites and if active forest management is practiced over the course of a rotation. In fact, shortleaf pine is particularly resistant to fusiform rust, which is very detrimental to other southern pine species (Guldin 1986). Certain stand management activities often increase the risk of major losses due to insect and disease, such as planting shortleaf pine without adequate and properly timed site preparation on recently harvested sites and not conducting thinnings when stands begin to lose vigor (Tainter 1986). The insect pests of shortleaf pine are Nantucket pine tip moth, pales weevil, pitcheating weevil, redheaded pine sawfly, pine engraver beetles, black turpentine beetle and southern pine beetle with the bark beetles being the most serious. The fungal pathogens are pitch canker, comandra blister rust, annosum root rot and littleleaf disease, with littleleaf disease being the most common.

Nantucket pine tip moth affects shoots and buds of young trees. Only trees under 15 feet in height are affected. Symptoms of attack include growth of adventitious buds or a lateral branch becoming the central leader on the stem below a killed terminal shoot. Stem deformities, presence of more knots in the wood, more prevalent compression wood, and growth reductions are all possible long-term symptoms as well. Areas that received mechanical site preparation and herbaceous weed control are more prone to attack due to the allure of more vigorously growing and nutritious pine seedlings. Insecticides such as disulfoton, dimethoate and azinophosmethyl are registered for and may be used to control Nantucket pine tip moth, but are not cost effective over large areas (Tainter 1986, Yates et al. 1981).

Pales weevil and pitcheating weevil cause similar types of damage to Nantucket pine tip moth in first-year shortleaf pine plantings. The adults of these two species feed on the bark and phloem of seedlings causing girdling of branches or the central stem of the seedling. White, crystallized resin forms over the wounds after feeding has occurred (Nord et al. 1984). Not all sites are susceptible to these reproduction weevils. Harvested sites that had pines as a component of the previous stand are the only susceptible sites. Weevils are attracted to freshly cutover pine areas where they breed in stumps and old root systems. Areas with planted seedlings that receive site preparation treatments after July 1 are most susceptible to infestation, while areas that receive site preparation treatments before that date usually do not have significant populations of these weevils (Tainter 1986). This cutoff date is related to when the weevils lay eggs and their overwintering habits. Three management options are available for sites that are prone to infestation by pales and pitch weevils. The first is harvesting susceptible stands prior to July 1. The second option is delaying regeneration plantings for one year after a harvest so that weevil populations will reduce or migrate to other areas. The third option is insecticides for high-value stands. Options two and three may not be economically feasible for large-scale operations.

Several species of *sawflies* can cause damage to shortleaf pine, but **redheaded pine sawfly** is by far the most damaging (Lawson 1990). This insect is a defoliator of trees less than 15 feet tall. Complete defoliation of trees can occur when several generations of sawflies occur in one year. Trees can typically survive a severe defoliation, but reductions in growth will occur. Infestations are most severe in stagnant, young trees that are receiving intense interspecific and intraspecific competition in plantations, and where pines are planted on unsuitable sites (Wilson and Averill 1978). Control of redheaded pine sawfly is best performed by keeping seedlings growing vigorously and reducing unwanted competition in plantation settings. Planting seedlings at wider spacings can also reduce the likelihood of redheaded pine sawfly infestation.

Pine engraver beetles feed on a variety of southern pine species. Four common pine engraver beetle species in the South are in the genus *Ips.* These small beetles feed on the phloem just underneath the bark, which girdles the tree, introduces fungi to the tree, and reduces wood quality. They can also kill the tree. The first symptom of infection is a gradual fading of needles from green to yellow and eventually to a reddish-brown color. Pitch tubes, or globs of dried resin resembling popcorn, occur with some trees, while a collection of reddish boring dust may be found in bark crevices and at the base of the stem in weak or low vigor trees. Y- or H-shaped galleries are evident beneath the bark of infected trees (Hale et al. 2002). Death of a tree will occur more quickly in warm weather than in cooler weather. Pine engraver beetles are attracted to areas where recent harvests of pines have occurred and heavy logging slash remains. Trees that are stressed due to drought, damaged or scarred from timber management activities, disease, and high levels of competition are also prone to infestation. Management of engraver beetles involves keeping trees growing vigorously. This can be accomplished through regular thinnings, prescribed burns to reduce fuels and competition, removal of dead or dying stems, and planting pines on appropriate sites.

Black turpentine beetle and southern pine beetle are the two most damaging insects of mature shortleaf pine trees. Symptoms of southern pine beetle and black turpentine beetle attacks are similar to those associated with pine engraver beetles except for two noticeable differences. The first is pitch tubes associated with entry wounds created by black turpentine beetle occur at or below 8 feet on mature trees, whereas entry wounds and pitch tubes found with southern pine beetles typically occur above 10 feet on the boles of mature trees. Black turpentine beetles do not introduce blue stain fungi into the tree like southern pine beetle (Hale et al. 2002). The second difference is the S-shaped galleries found just under the bark associated with southern pine beetle infestations.

All stages of the southern pine beetle (egg, larva, pupa and adult) can be found in the S-shaped galleries. One life cycle or generation of beetles from egg to adult takes place in 26 to 54 days depending on the season. Beetle development is much faster during the summer with warmer temperatures than in the winter. Pine beetle populations are cyclic. Outbreaks occur every 10 to 12 years in Tennessee and last two or three years. Beetle populations decline when winter temperatures stay below freezing for a week or more and populations tend to build during mild winters. Southern pine beetle is a native insect, reported in Tennessee during the mid-1750s.

Environmental stresses, especially drought, are the main culprits of infestations. Maintaining healthy, vigorous trees should be the primary management goal for avoidance of these beetles. Overstocked and overmature stands are most susceptible to the beetles. Management once an infestation occurs can be accomplished through sanitation removal and cut-and-leave methods. A buffer strip that is 40-100 feet wide should be created first around an active head (the direction the infestation is moving) to slow the spread of the beetles with sanitation operations. With the cut-and-leave method, freshly infested trees should be cut first and then the buffer should be cut around the infested area. All trees should be felled with their crowns toward the center of the infested area (Tankersley 2001). Salvage operations can be performed once the buffer strip is created around the active head.

Every life stage of shortleaf pine can be affected by **pitch canker**. Pitch canker causes open decay or necrotic spots (cankers) on stems and branches along with increased resin flow and resin soaking under the canker face that extends to the pith of the branch or stem (Starkey et al. 2007, Tainter 1986). Pitch canker develops in trees affected by severe weather or environmental stresses. In addition, excessive nitrogen in the soil may cause outbreaks of pitch canker (Starkey et al. 2007). Direct control of pitch canker is not feasible and is typically considered uneconomical. Some cultural steps that can be taken to avoid tree damage or death by pitch canker include planting shortleaf pine on suitable sites, thinning pure shortleaf pine stands before growth stagnates, and avoiding wounding of trees during any intermediate operations.

Comandra blister rust can be a severe pathogen of shortleaf pine if the alternate host for the disease, bastard toadflax (*Comandra umbellata*), is found in an area. Though uncommon, this pathogen has been found on the Cumberland Plateau of Tennessee (Tainter 1986). Shortleaf pines of all ages and sizes can be attacked by this rust. Symptoms include whirls of dead branches around the trunk where the pathogen enters the tree. Above this entry point the tree dies, creating a characteristic symptom called a spike top. It may take many years for older, larger trees to die from comandra blister rust, whereas younger trees will die more quickly. Management of this pathogen is difficult due to the need for control of the alternate host plant. If infected trees are found in a stand, remove them as soon as possible (Johnson 1986).

A common disease of shortleaf pine throughout its range is **annosum root rot**. This disease occurs most frequently in trees growing on deep, well-drained sandy soils. The higher the surface sand content of the soil, the greater the incidence of this disease (Tainter 1986, Wilson 1963). Annosum root rot only affects stands that have been thinned or had individual trees removed (Cram 2009). Spores are spread to stumps by wind or rain and then infect neighboring trees through root graphs. Aboveground symptoms may not be evident until half the root system is infected. Brown needles and yellowish tufts of needles at twig tips can be symptoms as well as irregular masses of white fungus that form between bark scales followed in time by brown, leathery conks with white margins and cream-colored lower surfaces (Cram 2009). Shortleaf pine dominated stands on high-risk, sandy soils should be managed for annosum root rot. Planting stems at greater spacings (10 feet by 10 feet or greater) will delay the need for thinning. Immediately following thinnings, stumps should be treated with borax to prevent entry of the fungus (Cram 2009).

Littleleaf disease is the most damaging pathogen of shortleaf pine throughout its native range, and death of the tree typically occurs within six years after infection (Mistretta 1984). This root rot affects 20- to 50-year-old trees on clay soils with poor drainage and soils that are severely eroded, shallow in depth and/or low in fertility. The pathogen disrupts nitrogen absorption by the roots. Diseased trees contain low amounts of nitrogen compared to healthy trees. Nitrogen fertilization can be used during early stages of the disease to amend symptoms and maintain growth rates. Symptoms of the disease are similar to annosum root rot, and distinguishing between the two can be difficult in early stages of infection (Tainter 1986). Newly infected trees display a yellowing and shortening of needles and reduction of shoot growth (Table 3). As the disease progresses, crowns appear thin and tufted. All needles drop off the tree except those near the tips of the branches. Branch death begins in the lower crown and progresses upward, and growth rates reduce dramatically by this point. Three years after infection, trees produce many smaller-than-normal cones containing sterile seed. Often when the tree dies, these cones will be retained on the stem and are a good diagnostic for littleleaf disease death of individual trees (Mistretta 1984). Management of shortleaf pine on sites suspected of having littleleaf disease is best approached by identifying high- or moderate-risk sites by using soil rating systems developed by Campbell and Copeland (1954). Effective stand management guidelines for mature trees that display littleleaf disease symptoms (Table 4) have been developed by Campbell et al. (1953).

Table 3. Littleleaf disease symptoms at three stages of development in mature shortleaf pine that is between 20 and 50 years old. Table is adapted from Campbell and Copeland (1954).

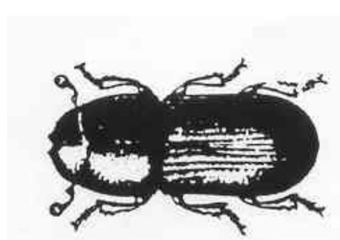
Symptoms Progression	Characteristics
Early Stages	A slight yellowing of the foliage on the current year needles occurs, needles are shorter than usual and shoot growth is reduced. It is difficult to distinguish early symptoms from malnutrition or other pathogens.
Middle Stages	Sparse and tufted foliage is present resulting from the progressive annual shortening of needle and twig growth. Needles turn a yellow-green in the fall and winter and usually become a more normal green during spring and early summer.
Late Stages	Starting in lower portions of the tree, twigs and branches die throughout the crown and sprouts may develop on the bole and branches. Just before mortality occurs, foliage is confined to the end of the branches. Trees killed by littleleaf typically have larger numbers of smaller cones.

Table 4. Cutting rules for lightly, moderately and severely diseased stands, assuming that littleleaf trees live an average of seven years from the onset of symptoms and those in advanced stages less than three years. Adapted from Campbell et al. (1953).

Infestation Level	Treatment
Light	Where only an occasional shortleaf pine shows littleleaf symptoms, cuts can be light and spaced at least 10 years apart.
Moderate	When between 10 and 25 percent of the trees show unmistakable littleleaf symptoms, cut on at least a 7 year cutting cycle, cutting all diseased or suspected trees.
Heavy	Where more than 25 percent of trees show signs of littleleaf symptoms, cut all shortleaf pine as soon as practical from the standpoint of merchantability, since such stands are likely to deteriorate very rapidly one 1/4 of the trees are obviously diseased.

The **white pine weevil** can seriously impact the growth of young eastern white pine by causing the terminal leader to die back. The weevil can create stem deformation, increase the susceptibility to wood decay organisms, reduce growth, and increase tree mortality. Weevil attacks can reduce tree height growth by 50 percent annually and when the dominant leader is removed, the tree will develop forks, crooks or become bushy. Early white pine weevil evidence is apparent in the spring when tiny droplets of resin are exuded from feeding punctures made by the adult insect. Larvae will girdle the leader and cause the needles of the tree to wilt. Eastern white pines infested with the weevil will appear either with brownish needle whirls or may appear completely white as pitch from the tree crystallizes along branches.

Trees grown in open spaces that receive full sunlight on the terminal shoots are vulnerable to weevil attack. The preferred method of stand protection is finding the balance between shade from crown closure and adequate light to maintain tree growth. Stands established under a hardwood canopy have shown lower susceptibility levels for weevil outbreak. Maintaining high densities of young white pines until the stand reaches 20 feet high has also reduced the level of weevil damage. Chemical treatments are available, but these should only be considered when more than 5 percent of the trees are infested and an economic evaluation warrants such a decision.



Managing Pine Stands for Wildlife

Craig A. Harper
Professor
UT Forestry, Wildlife and Fisheries

A common notion exists that pine stands are "biological deserts." Many folks believe pine stands (in particular, pine "plantations") harbor fewer wildlife species and support reduced numbers of individual animals. Furthermore, it is commonly expressed that plant species richness is drastically reduced in pine stands and understory development is often nonexistent. However, not all pine stands are void of wildlife. The value of a pine stand for wildlife is strongly associated with the composition and percent cover of herbaceous vegetation. When planned accordingly and managed correctly, pine stands (including pine plantations) harbor and support incredibly diverse plant and wildlife communities.

Initial Planning and Objectives

Managing pine stands with wildlife management as an objective begins in the planning stages. Proper site preparation for pine plantings includes clearing the site of slash and debris (if the site was previously forested and subsequently harvested) and/or spraying competitive non-native grasses (if the site was previously a hayfield or pasture). The technique used to prepare the site prior to planting is critical if wildlife management is an objective. A little extra effort at this stage will pay great dividends later in terms of enhancing the area for wildlife.

On previously forested, recently harvested sites, it is important to burn the area using prescribed fire prior to planting. This helps clear the area for tree planting equipment and, more importantly for wildlife, reduces the litter layer and stimulates seed in the seedbank to germinate. A lush stand of forbs and native warm-season grasses creates favorable conditions for wildlife by providing seed and forage, as well as nesting and brooding cover for many birds. Because prescribed fire will likely be used as a management tool throughout the life of the stand, a firebreak (approximately 20 feet wide) should be planned and retained around the perimeter of the stand.

The vast majority of fields in Tennessee have been planted to tall fescue at some time in the past. Before planting pines in a field, it is imperative to spray and kill existing sod-forming grasses (e.g., tall fescue, orchardgrass and bermudagrass) if wildlife management is an objective. These grasses offer poor forage for wildlife, harbor reduced numbers of invertebrates (primary food for upland game bird poults), preclude seed in the seedbank from germinating (thereby reducing vegetative diversity and food availability in the form of forage and weed seed), and provide a structure that is too dense and thick to permit adequate travel by upland game bird poults and other small wildlife. Merely spraying a strip of herbicide where the pines are to be planted is not sufficient. To realize the benefits of managing a pine stand for wildlife, the entire field must be sprayed. The benefits will be evident in the short term (one to five years) and in the long term (30+ years) as well.

Planting — Wider Is Better

Typically, pines are planted 6-8 feet apart in rows 6-8 feet apart, resulting in 680-1,200 trees per acre. A wider spacing should be used when wildlife management is an objective. Planting trees 10-12 feet apart in rows 12 feet apart allows more sunlight to reach the forest floor, which stimulates increased growth of forbs and grasses, providing enhanced nesting habitat, increased forage, and seed production and invertebrate availability. This wider spacing also allows a tractor to be driven into the stand later when disking and herbicide application are necessary. Where wildlife management is the sole objective, an even wider spacing (e.g., 25 feet or more) may be used to maintain the early successional growth stage for a longer period. Planting at the wider spacing will result in lower quality timber and very little economic return from the growth of the trees.

The herbaceous vegetation stimulated by the recommended site preparation techniques and wider spacing at planting should provide attractive habitat for wildlife (e.g., bobwhite quail, rabbits, woodcock, foxes, bluebirds, wild turkeys, bobcats, pine warblers, white-tailed deer, owls, indigo buntings, bats and hawks) that frequent or require early successional habitats for approximately five years (depending on the site). At this time, the trees will have grown to the point that a considerable amount of shade is cast and vegetative growth at ground level will be reduced. The stand will appear quite “thick.” From this stage until the first thinning, the stand provides excellent bedding cover for deer and thermal cover for many species of birds during winter.

Thinning and Prescribed Burning — Essential for Quality Wildlife Habitat

Most pine stands are ready for the first commercial thinning approximately 12 to 20 years after planting (depending on site). Thinning at this time reduces competition for sunlight, moisture and nutrients among residual trees and improves the health, vigor and growth rate of the stand. If thinning does not occur, the stand will slowly thin itself over time with a much-reduced growth rate. The increased sunlight provided by thinning also stimulates increased herbaceous growth on the forest floor, providing many of the benefits for wildlife described above.

A second commercial thinning is recommended five to 10 years later. When managing for wildlife, this thinning should remove enough trees to reduce the basal area to at least 25 square feet below the 50-year site index or to the point where 40-60 percent of the ground is open to direct sunlight. Generally, this is no more than 60-80 square feet per acre and even less (approximately 40-60 square feet) when bobwhite quail is the focal species. Often, scattered oaks (as well as other mast producers) occur within pine stands. When the second thinning is implemented, these mast producers should be identified and the ones with good form left to become established in the canopy. This will increase food availability within the stand in the future.

Thinning and burning go hand in hand. Prescribed burning in a closed-canopy stand does not stimulate the understory response desired when managing for wildlife. Likewise, thinning without burning does not produce the quality or composition of vegetation response that occurs after burning. There are many benefits in using prescribed fire throughout the life of a pine forest. Reduction of forest litter that serves as fuel for a wildfire is obviously important. Burning also stimulates vegetation wildlife use for food and cover and helps control undesirable hardwood encroachment in the stand. Perhaps most importantly (in terms of wildlife management), prescribed fire enhances the structure of understory vegetation for birds that nest on or near ground level, including wild turkeys, ruffed grouse, bobwhite quail and many songbirds. Typically, an “umbrella canopy” of forbs is the result, creating optimum brood-rearing conditions, as chicks are able to travel about with ease in search of invertebrates and seeds under the umbrella of “weeds.” Most prescribed burning is completed during late winter under relatively cool, moist conditions. Burning at this time reduces available cover and forage for only a short time, as spring green-up occurs within two to three weeks.

Pine stands may be burned once the trees (loblolly or shortleaf) are approximately 20 feet tall with a diameter of 4 inches at breast height. Prescribed fire should be used after each thinning once the trees reach this size. Thereafter, pine stands should be burned at least every four years. When bobwhite quail is the focal species, burning should be conducted annually within some stands or sections of stands.

Sawtimber Rotation

A decision must be made once the stand reaches 30 to 40 years old. At that time, the stand can be clearcut for saw logs and/or chipping or the stand can be thinned and managed for long-rotation sawtimber. As mentioned earlier, the recommended basal area is priority-driven. Typically, pine stands managed for wildlife should be maintained at approximately 60-80 square feet of basal area per acre. However, if bobwhite quail is the primary species for management, basal area should be reduced to 40-60 square feet per acre. Look for oaks and other mast producers that have good form. Retain these for increased food production.

Dead trees (called snags) should be left standing. Snags provide a food source for woodpeckers and other birds, including brown creepers, nuthatches and bluebirds in search of invertebrates. Later, the cavities initially excavated by woodpeckers serve as nesting and denning cavities for many species, including other woodpeckers, bluebirds, owls, flycatchers, chickadees, wrens, titmice, nuthatches, brown creepers, wood ducks, hooded mergansers, squirrels and raccoons. Thus, it is obvious how some trees (e.g., maples, elms, sweetgum, ash, sourwood and sycamore) can provide more for wildlife when dead than alive!

As the stand reaches the age for harvest, consider management strategies that will make the next stand more attractive for wildlife. Usually, hardwoods are found along creeks and low-lying areas. Oaks and other mast producers are normally included in these areas. These trees should be retained to enhance the future stand. Streamside management zones (SMZs) left uncut along drainage areas are important not only for hard and soft mast production, but also for travel corridors connecting other forest stands adjacent to the harvested stand. Optimally, SMZs left for wildlife should be at least 100 feet wide.

Different Ages, Different Structure

Pine stands (as well as other forest types) of different ages provide habitat for different wildlife species and various life stages of those species. For example, a wild turkey hen may nest in a 3-year-old pine stand, use a 20-year-old stand for thermal cover in winter and roost in a mature stand at any time of the year. To provide habitat for a diversity of wildlife and various life stages, stands should be separated in time and space. Therefore, it is good to have stands of various ages and entire stands should not necessarily be treated (managed) all at once. For example, it may be best to thin a portion of a stand one year and wait two or three years before thinning another section or the rest of the stand. Likewise, a section(s) of a stand may be harvested at 30-40 years, while another section (or sections) is left and managed for long-rotation sawtimber. By dividing the stand into several sections (e.g., 10- to 50-acre blocks), different stages of vegetation growth (succession) can be maintained.

The same is true when using prescribed fire. Some sections should be left unburned to provide standing cover and food resources while the burned section(s) develops. The unburned section(s) can be burned the next year or two to three years later. Large stands should be broken up by establishing firebreaks throughout the stand, creating sections (e.g., 10- to 50-acre blocks) in a checkerboard fashion. Thinning and burning on a rotational cycle produces a mosaic of habitat conditions and successional stages throughout the stand. Managed as such, the area will be attractive to more wildlife species and lead to increased use of the stand.

Hardwood Control

Several hardwood species (e.g., oaks, hickories, persimmon, cherry) are desirable for wildlife; however, many of the hardwoods that encroach upon pine stands initially are of limited value. These include red maple, sweetgum, winged elm, ash and sourwood. These hardwood “weeds” compete for sunlight and nutrients, reducing desired understory vegetation. Encroachment of these hardwoods is particularly problematic during the first five years after planting. The use of hardwood selective herbicides (e.g., imazapyr) is recommended because legumes (the single most important herbaceous plant group for wildlife) and other preferred wildlife plants, such as blackberry, are not harmed. Depending upon the age of the stand, control of hardwoods can be achieved through three techniques: mechanical thinning, herbicides and prescribed fire.

Mechanical control is usually the least effective, unless followed by herbicides and/or burning because of the tendency of sprouting, which results in more stems per acre. The most effective hardwood control technique is an herbicide application applied over the foliage when the stand is young (2-5 years). According to stand size, this can be accomplished via helicopter, a tractor or four-wheeler with a boom sprayer or with a backpack sprayer (typically used for spot-spraying individual trees). Herbicides may be applied to the cut surface of larger trees that have been girdled with a chainsaw or frilled (hacked) with a hatchet. The herbicide is applied with a hand-held squirt bottle.

Hardwood control is often needed in older (30+ years) pine stands that have not been managed previously through thinning or burning. After thinning these older stands, an aerial application of herbicide is recommended the following growing season to control residual hardwood stems. Following the herbicide application with prescribed fire will stimulate increased herbaceous growth and improve forage and seed availability. Another approach to controlling hardwood sprouts and saplings is to use a growing-season burn. Using prescribed fire in April, just as the leaves on deciduous hardwood trees are beginning to develop, is an excellent time to control unwanted seedlings and saplings.

Managing Openings, Firebreaks and Old Logging Roads

To meet the needs for a variety of wildlife species, 25-50 percent of the property should be in early successional openings. In many cases, this is not possible; nonetheless, an effort should be made to maintain at least 15-25 percent of the property in openings if wildlife management is the primary objective. This includes forest openings as well as old logging roads (or "woods roads") and firebreaks. It is important to note that openings are not necessarily "food plots." The primary objective in creating and managing openings is to provide habitat for a number of wildlife species that require early successional vegetation. The percentage of openings that are planted is based on the wildlife species targeted for management. For many wildlife species, planting is not necessary to create favorable habitat in openings. The seed of a wide variety of forbs and grasses important to wildlife lie dormant in the top few inches of soil (the seedbank). If allowed to germinate, these plants will provide the food (forage and seed) and cover required by species that use openings. These "natural" openings are maintained and managed with prescribed fire and light disking.

If an existing opening contains a sod-forming grass (especially tall fescue, orchardgrass and bermudagrass), it is critical that it be sprayed and killed to eliminate competition and allow seed in the seedbank to germinate. Germination is then stimulated by burning the field and light disking. A firebreak is needed around the perimeter of the field and, according to field size, may be used to divide the field into sections. Various sections then can be managed differently to provide a mixture of successional stages and plant types. The perimeter firebreak around openings should not be established directly adjacent to the woods. Approximately 50 feet should be left between the woods and the firebreak for a soft edge to develop, creating a zone of escape cover (e.g., brush, brambles, briars, tall grasses and weeds) available to wildlife using the opening. This is also advantageous if the firebreak is planted because it reduces the shade effect and competition for nutrients from the adjacent trees. Additional soft edge can be created around openings by heavily thinning a zone 50 feet wide just inside the woods edge.

Some openings (or a portion of) should be burned and/or disked annually, while others are treated every two, three or four years to provide a range of successional stages from bare ground up to 4-year "rough." (Note: firebreaks surrounding and within the pine stand should be included in the rotational disking schedule.) This strategy will ensure that nesting cover, brooding cover and escape cover are always present within some of the openings. It is usually best to burn in late winter, just prior to spring green-up. Disking should be completed from November through February, depending on the response from the seedbank. Initially, it may be necessary to disk one strip per month through the winter to identify the best time to disk in a particular area. The preferred composition of plants in disked areas include ragweed, partridge pea, beggar's-lice, panicgrasses, milk pea, butterfly pea, blackberry, morning glories, wild geranium and native lespedezas. These plants provide excellent brood cover for quail and turkeys, quality forage for deer and rabbits and abundant seed production for a variety of birds. Fields containing native warm-season grasses (NWSG) provide excellent nesting habitat for ground-nesting birds. Manage openings containing NWSG on a two- or three-year rotation by burning half of the fields (or sections) each year. This strategy ensures some nesting cover is available each year.

Some of the firebreaks should be planted to provide a supplemental food source. For bobwhite quail, wild turkeys and other birds, at least half of the firebreaks should be planted to warm-season forage/seed mixtures (e.g., milo, millets, cowpeas, sunflowers, annual lespedeza and/or buckwheat). The other half may be left fallow if quail and songbirds are favored or planted to cool-season forages (e.g., clovers and wheat) if wild turkeys are favored.

Where white-tailed deer is the focal species, 2-5 percent of the property (including openings, firebreaks and old logging roads) may be planted in food plots containing quality forages. Ideally, half of these should be planted in warm-season mixtures (e.g., iron-clay cowpeas, lablab, reseeding soybeans, American jointvetch and alyceclover) and half in cool-season mixtures (e.g., various clovers, dwarf essex rape, Austrian winter peas, oats, wheat and rye). In areas where acorn production is limited, corn may be planted to half of the openings reserved for warm-season plantings. This strategy ensures forage is available during the two primary stress periods for deer — late summer and late winter. It is very important to match the planting to the site and to amend the soil with the recommended rate of lime and fertilizers as determined by a soil test.

Another way to enhance wildlife openings is by planting mast-bearing trees and shrubs. Recommended hard mast producers include any of the oaks (depending on site), American beech and chinquapin. Recommended soft-mast producers include apple, crabapple, persimmon, wild plum, pear, elderberry, hawthorn, cherry, dogwood and spicebush. Trees and shrubs may be planted across openings to create hedgerows, along edges where sunlight is adequate and in corners or odd areas. These trees and shrubs should be protected from prescribed fire.

Old logging roads that receive relatively little vehicular traffic should be planted to prevent soil erosion and provide additional forage and “bugging areas” for wildlife. Mixtures containing legumes (e.g., clovers and birdsfoot trefoil) and annual cool-season grains (e.g., wheat and oats) are recommended because they provide adequate soil stabilization, quality forage and harbor an abundance of insects and other invertebrates needed by turkey and quail chicks. Perennial cool-season grasses (e.g., tall fescue and orchardgrass) are not recommended because they provide virtually no benefit to wildlife.

Economic Considerations

Daniel Cassidy
National Program Manager, Bioenergy
USDA, National Institute of Food and Agriculture (NIFA)

Woodland owners can conduct forest management as a business by becoming more proactive. With today's rising costs and taxes, owners should consider more efficient management techniques. This may mean a change in thinking for many woodland owners. Non-industrial private landowners make up more than 80 percent of the forest base in Tennessee and are the key to supplying the raw materials needed by forest industries.

Forests as Investment Instruments

Consider our forests as investments, especially as trees grow into merchantable sizes. Merchantable trees represent a value that could be obtained by selling the tree. This return or value could then be used or invested in any number of ways, depending upon each landowner's personal desires and needs. To manage our forests wisely, we must be able to compare these returns to other investments or businesses. Landowners need to know what their timber investment choices are and the return they are expecting to receive in order to make sound management choices.

Timber is a unique investment. The investment period is often extended, represented by a long period of time while the trees reach marketability. At the same time, product classifications allow landowners great flexibility in when they choose to liquidate the investment. Sometimes overlooked recreation, hunting and other non-market opportunities are associated with the investment. Risk is also unique with timber investments, for there is a real risk in a complete and unexpected loss in the value of the investment due to fire or insect damage.

Examining the Investment

By expressing tree growth in terms of compound interest, forest investments can be compared with other enterprises. The rate of compound interest of stands can be determined with a simple growth study or by comparing inventories. Divide the past volume of the stand by the present volume. The factor obtained is then applied to compound interest tables to determine the compound annual rate of interest returned.

We know that as trees age, vigor and growth tend to decline. As growth rates diminish, so does the earning power of the tree. Even if trees grow at the same rate year after year, the interest they return decreases each year. This is because as their volume increases, the same amount of wood added annually represents a smaller percent return each year. For example, $0.05 added to $0.50 would represent a 10 percent increase, while $0.05 added to $1 represents only a 5 percent increase.

With this in mind, we can easily see that somewhere along the line, tree growth returns will drop below an acceptable level. At this point, trees might be considered financially mature. The time to reach this level will vary from site to site. Some individuals will demand a higher return on their investment than others and will make a final harvest before those who will accept a lower rate of interest. Three common ways tree interest rates may be used include determining when to cut stands, selecting trees to cut when removing individuals and determining whether to cut immature timber to liquidate debt.

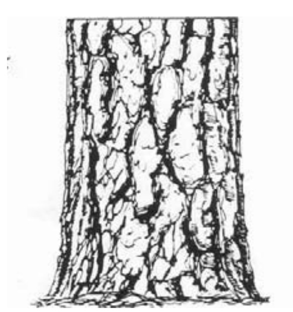
Sometimes interest rates may be misleading. In crowded stands, low interest rates may only indicate a need to thin the stand. Often the removal of the slower-growing individuals will immediately boost the interest to acceptable rates. Sparse stands may show good growth, but due to the small number of trees, they are not paying for the use of the land. Cut and re-establish such stands so that the full site can be utilized. In determining the minimum acceptable rate of growth for trees, it is necessary to consider net return. Such factors as income taxation, handling costs, risk and flexibility of operations may make a lower rate of return more acceptable. And finally, as timber reaches large sizes, trees become more suitable for higher-valued products. Be sure to check on these markets before liquidating a stand that might appear to be financially mature.

Investment Advantages and Disadvantages

Many opportunities exist to advance the quality of timber stands with active management. Timber production can be timed to provide periodic returns. This income can be a means of paying taxes on land held for future use for heirs under an estate plan. Timber income qualifies for capital gains tax treatment, which is considerably lower than taxes on ordinary income. Reforestation investments are often eligible for cost-share programs and can be amortized as well as provide immediate tax credits up to 10 percent of costs. Above all this, timber adds diversification to investment portfolios. Timber prices have historically increased at a rate of 2 to 4 percent above inflation, while the annual physical growth of timber increases 4 to 8 percent in addition to “economic growth.”

Forest investments are, however, long-term propositions. The risk is real in the form of fire, insects, disease and environmental/social constraints. Often there is a heavy front-end capital investment required for stand initiation and loans for forestry investments can be difficult to acquire. Timber buyers are not attracted to small tracts and the costs of additional land purchases may be prohibitive for forestry investments. Fluctuations in price may be on a longer time-scale. Management returns are usually correlated to the intensity of management applied.

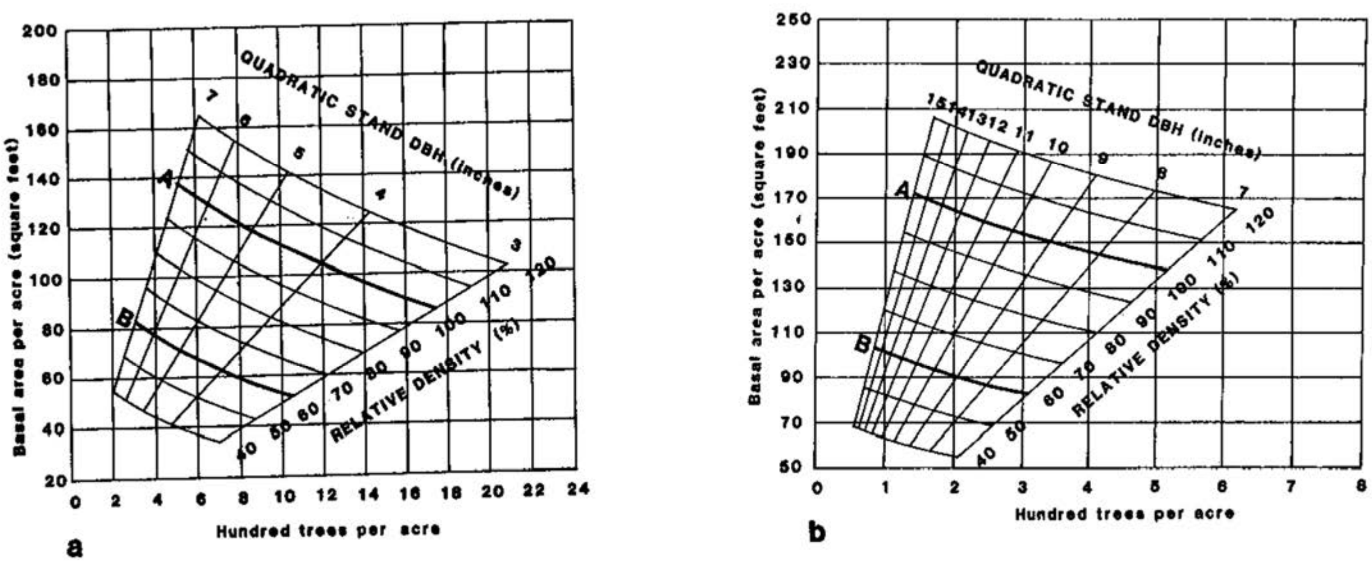
Forestry is a strong economic force in Tennessee. Forest investments make a sound choice in diversifying investment portfolios, as well as a financial resource that can be passed from generation to generation.



Summary

Pines are a very versatile genus and species group, occurring in the Coastal Plain, the Highland Rim, the Cumberland Plateau, the Ridge and Valley, and the Appalachian Mountains on a variety of soils. Under proper management, the pines, and particularly shortleaf pine in several community types, can meet habitat and monetary objectives to satisfy public and private desires of forest property owners.

Forest management is not a "cookie-cutter" science. Working with pines can provide landowners with an additional opportunity to achieve their management objectives. This guide describes various management opportunities with the goal of encouraging pro-active management of pines. The pine resource has historically had a place in the development of Tennessee and should be treasured just as much as our hardwood heritage. Hopefully, this handbook has inspired you to contact your local forester or consultant and embrace pine management as a possibility for environmental and economic diversity, wildlife habitat, recreational opportunities or adding to the beauty of Tennessee.



Shortleaf pine stocking guide comparing the relationships of basal area, number of trees, and average tree diameter (diameter of the tree of mean basal area) in calculating relative density. The area between curves A and B on the charts indicates the range in relative density where trees can fully utilize growing space, i.e., fully-stocked. Area above curve A is considered overstocked and the area below curve B is understocked. Adapted from Rogers (1983).

Literature Cited

Abrams, M.D. 1998. The red maple paradox. Bioscience. 48(5): 355-364.

Alig, R.J., J.D. Kline, M. Lichenstein. 2004. Urbanization on the US landscape: looking ahead in the 21st century. Landscape and Urban Planning. 69: 219-234.

Arnold, D.; Fly, M.; Griffin, A.; Hancock, G.; Kirk, R.; Kirksey, J.; and others. 2010. Tennessee forest resource assessment and strategy. Tennessee Department of Agriculture Division of Forestry. Nashville, TN. 180 p.

Baker, J.B. 1982. Natural regeneration of loblolly/shortleaf pine. In: Proceedings of Low Cost Alternatives for Regeneration of Southern Pines Conference. Georgia Cooperative Extension Service, Athens, GA: 31-50.

Baker, J.B. 1992. Natural regeneration of shortleaf pine. In: Brissette, J.C.; Barnett, J.P., eds. Proceedings of the Shortleaf Pine Regeneration Workshop. 1991 October 29-31; Little Rock, AR. General Technical Report SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 102-112.

Baker, J.B.; Cain, M.D.; Guldin, J.M.; Murphy, P.A.; Shelton, M.G. 1996. Uneven-aged silviculture for the loblolly and shortleaf pine forest cover types. Gen. Tech. Rep. SRS-118. Asheville, NC: U.S. Department of Agriculture, Forest Service. Southern Research Station: 65 p.

Barnett, J.P.; Brissette, J.C. 2004. Stock type affects performance of shortleaf pine planted in the Ouachita Mountains through 10 years. General Technical Report SRS-71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 420-422.

Barnett, J.P.; Brissette, J.C.; Carlson, W.C. 1986. Artificial regeneration of shortleaf pine. In: Murphy, P.A. ed. Symposium on the shortleaf pine ecosystem; 1986 March 31-April 2; Little Rock, AR. Arkansas Cooperative Extension Service, Monticello, AR: 64-88.

Burger, G.; Keyser, P.D. Ecology and management of oak woodlands and savannas. University of Tennessee Extension Publication PB 1812. 9 p.

Burkhart, L.J.; Gilmore, A.R.; 1967. Twenty-nine years growth and thinning yields in a shortleaf pine plantation in southern Illinois. Transactions of the Illinois State Academy of Science. 60: 100-103.

Cain, M.D.; Shelton, M.G. 2002. Does prescribed burning have a place in regenerating uneven-aged loblolly-shortleaf pine stands? Southern Journal of Applied Forestry. 26: 117-123.

Campbell, W.A.; Copeland, Jr. O.L. 1954. Littleleaf disease of shortleaf and loblolly pines. U.S. Department of Agriculture, Forest Service Circular Number 940. 41 p.

Campbell, W.A.; Copeland, Jr. O.L.; Hepting, G.H. 1953. Managing shortleaf pine in littleleaf disease areas. U.S. Department of Agriculture, Forest Service Station Paper Number 25. 12 p.

Cassidy, D. 2005. A southern pine management guide for Tennessee landowners. University of Tennessee Extension Publication 1751. 47 p.

Clabo, D.C. 2014. Shortleaf pine sprout production capability in response to disturbance. University of Tennessee, Knoxville. Master's Thesis. 76 p.

Clabo, D.C.; Clatterbuck, W.K. 2015. Site preparation techniques for the establishment of mixed pine-hardwood stands: 22-year results. Forest Science. 61(4): 790-799.

Conn, J. 2012. Nursery production of shortleaf pine at the east Tennessee nursery. In: Kush, J.; Barlow, R.J.; Gilbert, J.C, eds. Proceedings of the shortleaf pine conference: east meets west, bridging the gap with research and education across the range. 2011 September 20-22; Huntsville, AL. Auburn, AL: Alabama Agricultural Experiment Station Special Report No. 11: 7.

Cooper, A.W. 1989. Ecology of the pine-hardwood type. In: Waldrop, T.A. ed. Proceedings of pine-hardwood mixtures: A symposium on management and ecology of the type. 1989 April 18-19; Atlanta, GA. General Technical Report SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 3-8.

Cost, N.D.; Howard, J.O.; Mead, B.; McWilliam, W.H.; Smith, B.W.; Van Hooser, D.D.; Wharton, E.H. 1990. The forest biomass resource of the United States. Gen. Tech. Rep. WO-57. Washington, DC: U.S. Department of Agriculture, Forest Service. 21 p.

Cram, M.M. 2009. Annosum root rot. The Bugwood Network. The University of Georgia Warnell School of Forestry and Natural Resources and College of Agricultural and Environmental Sciences, Department of Entomology. http://www.bugwood.org/factsheets/98-031.html. [Date accessed: June 7, 2015].

Forest Inventory and Analysis (FIA). 2015. Net volume of live trees (at least 5 inches d.b.h./d.r.c.) in cubic feet, by species group and diameter class-Inventory-Tennessee-2012. U.S. Department of Agriculture, Forest Service. http://apps.fs.fed.us/fido/standardrpt.html. [Date accessed: 15 July 2015].

Guldin, J.M. 1986. Ecology of shortleaf pine. In: Murphy, P.A. ed. Symposium on the shortleaf pine ecosystem; 1986 March 31-April 2; Little Rock, AR. Arkansas Cooperative Extension Service, Monticello, AR: 25-40.

Guldin, J.M. 2007. Restoration and management of shortleaf pine in pure and mixed stands—Science, empirical observation, and the wishful application of generalities. In: Kabrick, J.M.; Dey, D.C.; Gwaze, D. eds. Shortleaf Pine Restoration and Ecology in the Ozarks: Proceedings of a Symposium. 2006 November 7-9; Springfield, MO. Gen. Tech. Rep. NRS-P-15. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Research Station. Missouri Department of Conservation: 47-58.

Guyette, R.P.; Muzika, R.M.; Voelker, S.L. 2007. The historical ecology of fire, climate, and the decline of shortleaf pine in the Missouri Ozarks. In: Kabrick, J.M.; Dey, D.C.; Gwaze, D. eds. Shortleaf Pine Restoration and Ecology in the Ozarks: Proceedings of a Symposium. 2006 November 7-November 9; Springfield, MO. Gen. Tech. Rep. NRS-P-15. Newtown Square, PA. Department of Agriculture, Forest Service, Northern Research Station. Missouri Department of Conservation: 8-18.

Gwaze, D.; Melick, R.; Studyvin, C.; Hoss, G. 2006. Survival and growth of container and bareroot shortleaf pine seedlings in Missouri. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D. tech. cords. National Proceedings: Forest and Conservation Nursery Associations – 2005. Proceedings RMRS-P-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 123-126.

Hale, F.A.; Burgess, G.; Robinson, D.K.; Kauffman, B.W.; Tankersley, L.A.; Windham, A.S. 2002. Forest pest control certification manual: C2. University of Tennessee, Entomology and Plant Pathology Agricultural Extension Service, Knoxville, TN. 39 p.

Halls, L.K.; Homesley, W.B. 1966. Stand composition in a mature pine-hardwood forest of southeastern Texas. Journal of Forestry 64(3): 170-174.

Hardin, J.W.; Leopold, D.J.; White, F.M. 2001. Shortleaf pine. Harlow and Harrar's Textbook of Dendrology. McGraw-Hill. New York. pp. 146-148.

Hare, R.C. 1961. Heat effects on living plants. Occasional Paper 183. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station. 34 p.

Johnson, D.W. 1986. Comandra blister rust. Forest Insect and Disease Leaflet 62. U.S. Department of Agriculture, Forest Service. 8 p.

Burger, G.; Keyser, P.D. 2013. Ecology and management of oak savannas and woodlands. University of Tennessee Extension Publication 1812. 9 p.

Lawson, E.R. 1990. *Pinus echinata* Mill. shortleaf pine. In: Burns, R.M.; Honkala, B.H. (tech. cords.). Silvics of North America: Vol. 1. Conifers. Agriculture Handbook 654, Washington, DC: U.S. Department of Agriculture, Forest Service: 316-326.

Lilly, C.J. 2011. Shortleaf pine: The basal crook adaptations and the traits it infers to its hybrid with loblolly pine. Master's Thesis. Oklahoma State University, Stillwater, OK. 174 p.

Lilly, C.J.; Will, R.E.; Tauer, C.G. 2012. Physiological and morphological attributes of shortleaf x loblolly pine F1 hybrid seedlings: is there an advantage to being a hybrid? Canadian Journal of Forest Research 42: 238-246.

Little, E.L., Jr. 1971. Atlas of United States trees, vol. 1. Conifers and important hardwoods. Miscellaneous Publication 1146. Washington, DC: U.S. Department of Agriculture. 313 p.

Mann, C.S.; Gwaze, D. 2007. Direct seeding of shortleaf pine. In: Kabrick, J.M., D.C. Dey, D. Gwaze eds. Shortleaf Pine Restoration and Ecology in the Ozarks: Proceedings of a Symposium. 2006 November 7-9; Springfield, MO. Gen. Tech. Rep. NRS-P-15. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Research Station. Missouri Department of Conservation: 119-120.

Masters, R.M. 2007. The importance of shortleaf pine for wildlife and diversity in mixed oak-pine forests and in pine-grassland woodlands. In: Kabrick, J.M., Dey, D.C., Gwaze, D. Eds. Shortleaf Pine Restoration and Ecology of the Ozarks: Proceedings of a Symposium. Gen. Tech. Rep. NRS-P-15. Newtown Square, PA: U.S. Dept. of Agriculture, Forest Service, Northern Research Station: 35-43.

Mattoon, W.R. 1915. Life history of shortleaf pine. Bulletin 244, Washington, DC: U.S. Department of Agriculture, Forest Service. 46 p.

Mattoon, W.R. 1927. Shortleaf pine primer. Farmers' Bulletin No. 1534. Washington, DC: U.S. Department of Agriculture. UNT Digital Library. http://digital.library.unt.edu/ark:/67531/metadc9172/. [Date accessed: June 30, 2015]. 41 p.

McWilliams W.H.; Sheffield, R.M.; Hansen, M.H; Birch, T.W. 1986. The shortleaf resource. In: Murphy, P.A. ed. Symposium on the shortleaf pine ecosystem; 1986 March 31-April 2; Little Rock, AR. Monticello, AR: Arkansas Cooperative Extension Service: 9-24.

Mexal, J.G. 1992. Artificial regeneration of shortleaf pine: put it all together for success. In: Brissette, J.C., Barnett, J.P, eds. Proceedings of the Shortleaf Pine Regeneration Workshop; 1991 October 29-31; Little Rock, AR. Gen. Tech. Rep. SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 172-186.

Mistretta, P.A. 1984. Littleleaf disease. Forest Insect and Disease and Leaflet 20. U.S. Department of Agriculture, Forest Service.

Nash, A.J. 1963. A method of classifying shortleaf pine sites in Missouri. Research Bulletin 824. Columbia, MO: Missouri Agricultural Experiment Station. 53 p.

Nord, J.C.; Ragenovich, I.; Dogget, C.A. 1984. Pales Weevil. Forest Insect and Disease Leaflet 104. U.S. Department of Agriculture, Forest Service. 12 p.

Nyland, R.D. 2007. *Silviculture Concepts and Applications, Second Edition*. Waveland Press. Long Grove, Illinois. 682 p.

Olson, D.F., Jr., McAlpine, R.G. 1973. Oak-pine. In: Silvicultural Systems for the Major Forest Types of the United States. Agriculture Handbook 445. Washington, DC: U.S. Dept. of Agriculture, Forest Service: 83-84.

Oswalt, C.M. 2012. Spatial and temporal trends of the shortleaf pine resource in the eastern United States. In: Kush, J.; Barlow, R.J.; Gilbert, J.C., eds. Proceedings of the shortleaf pine conference: east meets west, bridging the gap with research and education across the range. 2011 September 20-22; Huntsville, AL. Auburn, AL: Alabama Agricultural Experiment Station Special Report No. 11: 33-37.

Oswalt, C.M.; Oswalt, S.N.; Johnson, T.G.; Brandeis, C.; Randolph, K.C.; King, C.R. 2012. Tennessee's forests, 2009. U.S. Department of Agriculture, Forest Service, Resource Bulletin SRS-189. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 136 p.

Phares, R.E., J.S. Crosby. 1962. Basal sprouting of fire injured shortleaf pine trees. Journal of Forestry. 60(3): 204-205.

Phillips, D.R.; Abercrombie, J.A. 1987. Pine-hardwood mixtures--A new concept in regeneration. Southern Journal of Applied Forestry 11(4): 192-197.

Phipps, H.W. 1973. Effects of thinning on young shortleaf pine plantations in Indiana. Research Paper NC-93. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Rogers, R. 1983. Guides for thinning shortleaf pine. In: E.P. Jones, Jr. ed. Proceedings of the Second Biennial Southern Silvicultural Research Conference; 1982 November 4-5; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service: 217-225.

Russell, T.E.; Mignery, A.L. 1968. Direct seeding pine in Tennessee's highlands. Research Paper SO-31. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 22 p.

Sheffield, R.M.; Birch, T.W.; Leatherberry, E.C.; McWilliams, W.H. 1989. The pine-hardwood resource in the eastern United States. In: Waldrop, T.A. ed. Proceedings of pine-hardwood mixtures: A symposium on management and ecology of the type. 1989 April 18-19; Atlanta, GA. General Technical Report SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 9-19.

Shultz, R.P. 1997. Loblolly pine: The ecology and culture of loblolly pine (*Pinus taeda* L.). Agricultural Handbook 713. Washington, DC: U.S. Department of Agriculture, Forest Service. 514 p.

Smalley, G.W. 1979. Growth and yield of shortleaf pine plantations. In: Williston, H.L.; Balmer, W.E. Prog. Coords. Symposium for the Management of Pines of the Interior South. 1978 November 7-November 8; Knoxville, TN. Technical Publication SA-TP2. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Area State and Private Forestry: 28-47.

Smalley, G.W. 1986. Stand dynamics of unthinned and thinned shortleaf pine plantations. In: Murphy, P.A. ed. Symposium on the shortleaf pine ecosystem; 1986 March 31-April 2; Little Rock, AR. Arkansas Cooperative Extension Service, Monticello, AR: 114-134.

Smalley, G.W.; Bailey, R.L. 1974a. Yield tables and stand structure for loblolly pine plantations in Tennessee, Alabama, and Georgia Highlands. Research Paper SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Experiment Station. 80 p.

Smalley, G.W.; Bailey, R.L. 1974b. Yield tables and stand structure for shortleaf pine plantations in Tennessee, Alabama, and Georgia Highlands. Research Paper SO-97. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Experiment Station. 56 p.

Smalley, G.W.; Bower, D.R. 1971. Site index curves for loblolly and shortleaf pine plantations on abandoned fields in Tennessee, Alabama, and Georgia highlands. Research Note SO-126. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station. 5 p.

South, D.B.; Buckner E.R. 2003. The decline of southern yellow pine timberland. Journal of Forestry 101(1): 30-35.

Stambaugh, M.C.; Guyette, R.P.; Dey, D.C. 2007. What fire frequency is appropriate for shortleaf pine regeneration and survival? In: Kabrick, J.M., D.C. Dey, D. Gwaze eds. Shortleaf Pine Restoration and Ecology in the Ozarks: Proceedings of a Symposium. 2006 November 7-November 9; Springfield, MO. Gen. Tech. Rep. NRS-P-15. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Research Station: 121-128.

Starkey, D.; Meeker, J.; Mangini, A. 2007. Pitch canker of southern pines and recent cases in Florida, Louisiana, Mississippi, and Texas. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D. eds. National Proceedings: Forest and Conservation Nursery Associations - 2006. Proceedings RMRS-P-50. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-103.

Sudworth, G.W.; Killebrew, J.B. 1897. The forests of Tennessee: their extent, character and distribution. Nashville, Chattanooga, and St. Louis Railway. Nashville, TN: Publishing House of the M.E. Church, South. 32 p.

Switzer, G.L.; Shelton, M.G.; Nelson, L.E. 1979. Development of the forest floor and soil surface on upland sites of the east Gulf Coastal Plain. Ecology 60(6): 1162-1171.

Tainter, F.H. 1986. Protection of shortleaf pine from insects and diseases. In: Murphy, P.A. ed. Symposium on the shortleaf pine ecosystem; 1986 March 31-April 2; Little Rock, AR. Arkansas Cooperative Extension Service, Monticello, AR: 235-247.

Tankersley, L. 2001. The southern pine beetle. Renewable Resource Notes, SP 482. The University of Tennessee Agricultural Extension Service. 4 p.

Tauer, C.G.; Stewart, J.F.; Will, R.E.; Lilly, C.J.; Guldin, J.M.; Nelson, D.C. 2012. Hybridization leads to loss of genetic integrity in shortleaf pine: Unexpected consequences of pine management and fire suppression. Journal of Forestry 110(4): 216-224.

Tennessee Department of Tourist Development. 2015. Welcome. http://www.state.tn.us/tourdev/ [Date accessed: July 21, 2015].

Walker, L.C.; Wiant, H.V. 1966. Silviculture of shortleaf pine. Bulletin 9. Nacogdoches, Texas: Stephen F. Austin State College School of Forestry. 60 p.

Wear, D.N.; Greis, J.G. 2002. Southern forest resource assessment – technical report. General Technical Report SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.

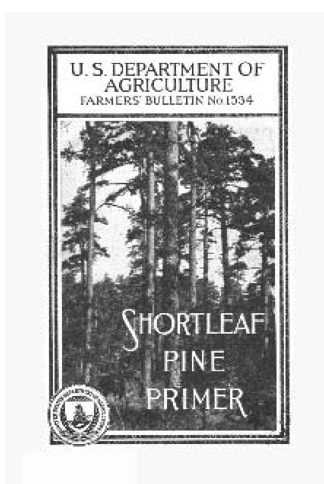
Williams, R.A. 1998. Effects of fire on shortleaf and loblolly pine reproduction and its potential use in shortleaf/oak/hickory ecosystem restoration. In: Waldrop, T.A. ed. Proceedings of the Ninth Biennial Southern Silvicultural Research Conference; 1997 February 25-27; Clemson, SC. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 321-325.

Wilson, C.L. 1963. *Fomes annosus* root rot of shortleaf, loblolly, and slash pine in Arkansas. Plant Dis. Reptr. 47:328.

Wilson, L.F.; Averill, R.D. 1978. Redheaded pine sawfly. Forest Insect and Disease Leaflet 14. U.S. Department of Agriculture, Forest Service.

Yates III, H.O.; Overgard, N.A.; Koerber, T.W. 1981. Nantucket pine tip moth. Forest Insect and Disease Leaflet 70. U.S. Department of Agriculture, Forest Service. 7 p.

Zedaker, S.M.; Smith, D.W.; Kreh, R.E.; Frederickson, T.S. 1989. The development of five-year-old mixed upland hardwood-pine stands. In: Waldrop, T.A. ed. Proceedings of pine-hardwood mixtures: A symposium on management and ecology of the type. 1989 April 18-19; Atlanta, GA. General Technical Report SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 100-106.



An example of a shortleaf pine – hardwood stand in Tennessee.

PB1751(REV) E12-4915-002-16 8/15 16-0024