Regenerating Longleaf Pine with Natural Seeding

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ABSTRACT

Natural regeneration is a practical and inexpensive option for existing longleaf pine (*Pinus palustris* Mill.) forests if all requirements for regeneration can be met. These requirements include an adequate seed supply, a seedbed of exposed mineral soil, timely control of competition, and protection of the established seedling stand. The shelterwood system appears best suited to the requirements of the species. The final harvest takes place only after a new stand is established so that the site is occupied while waiting for a good cone crop. The shelterwood stand maximizes per-acre seed production and produces sufficient needle litter to fuel fires hot enough to limit hardwood encroachment. Careful advance planning, annual monitoring of cone crops, regular regeneration surveys, and proper timing and execution of cultural treatments are essential to success.

INTRODUCTION

In presettlement times vast forests of longleaf pine (*Pinus palustris* Mill.) occupied a substantial part of the coastal plains of the southeastern United States, perhaps as much as 60 million acres (Wahlenberg 1946). The natural range of this species extends along the Atlantic and Gulf Coastal Plains from southeast Virginia south through the northern two-thirds of peninsular Florida and west to east Texas, with extensions into the Piedmont, Ridge and Valley, and Mountain provinces of Alabama and northwest Georgia.

The original longleaf pine forests occurred on a wide range of site conditions, from poorly drained flatwoods near the coast to dry, rocky mountain ridges at elevations up to 2,000 feet (Boyer 1990a). Longleaf pine has naturally regenerated itself for thousands of years. It is considered a fire subclimax forest type that perpetuates itself in conjunction with periodic surface fires (Boyer and Peterson 1983). The species is very intolerant of competition but comparatively resistant to fire and to many of the disease and insect pests that afflict other southern pines. In the past, frequent fires have kept longleaf forests clear of competing hardwoods and brush without seriously affecting fire-resistant grass-stage longleaf pine seedlings. Fires also provided a seedbed by removing surface litter so that large longleaf pine seeds could reach mineral soil and germinate.

Grass-stage longleaf seedlings grow quite slowly when overtopped but can respond quickly when released. Seedlings established under a parent overstory are released when single mature trees or small groups are killed by lightning and subsequent attack by bark beetles, the principal cause of mortality among large longleaf pines. Seedlings are similarly released following blowdown of parent trees, whether on a small scale by local storms and tornadoes or on a large scale by a severe hurricane. Lightning kills and small blowdowns often lead to patchy longleaf stands made up of several age and size classes; large-scale blowdowns create extensive even-aged stands. Established seedlings on the ground often are present to replace their fallen parents, as long as fires continue to exclude more vigorous hardwoods and other pines. Without fire, the latter would rapidly occupy openings, overtopping and suppressing slower growing longleaf pines.

Longleaf forests have been intensively exploited, beginning with the earliest settlers, for a wide variety of products and uses (Croker 1987). Logging of the original old-growth forest intensified early in the 20th century, reaching a peak in 1907 when an estimated 13 billion board feet were cut (Wahlenberg 1946). Logging progressed from east to west, and all merchantable trees were cut with little or no thought for regeneration. By 1935, according to an early forest survey (Wahlenberg

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1946), the resource was down to an estimated 20.4 million acres, of which 1.9 million acres were old growth. Second-growth longleaf forests naturally, and fortuitously, succeeded old growth on 12.4 million acres, while the remaining 6.1 million acres were unregenerated cutover. Since then, according to subsequent forest surveys (Kelly and Bechtold 1990), the longleaf forest type has further declined to 12.2 million acres in 1955 and to 3.8 million acres by 1985. The most recent surveys indicate that annual removals exceed growth by 98 million cubic feet or 43 percent. There have been declines in every diameter class from 1 to 15 inches, with increases only in the larger size classes, indicating a lack of regeneration as existing stands are cut (Kelly and Bechtold 1990). Nearly all remaining longleaf stands are of natural origin; only 9 percent have been planted. At present, the outlook for this forest type is not promising.

Regeneration of longleaf pine, either naturally or artificially, has been inhibited by several problems associated with this species. First, it is a poor seed producer; good seed crops are few and far between (Boyer 1987). Second, relatively few longleaf seeds survive to become established seedlings, partly because of the large number of predators that seek out these large, nutritious seeds (Boyer 1964). Third, because of the characteristic slow early growth of longleaf seedlings, they may spend years in the stemless grass stage before initiating height growth. However, these problems largely can be overcome. Although planning and care are required, longleaf pine can be regenerated naturally (Croker and Boyer 1975), by direct seeding (Mann 1970), and by planting (Mann 1969).

Selection of the appropriate regeneration option depends on several considerations, including site and stand conditions, management goals, financial resources, and planned rotation length. Natural regeneration, which utilizes seeds produced by mature trees in the area to be regenerated, costs the least but is applicable only to existing longleaf forests and may not be possible for all of these. Any restoration of longleaf pine to lands that it formerly occupied will depend on artificial regeneration.

REQUIREMENTS FOR NATURAL REGENERATION

Seed Supply

An adequate seed source must be present in the regeneration area. The size, number, and distribution of seed-bearing trees must be such that a cone crop with a minimum of 750, preferably 1,000 or more, cones per acre will occur during the time span allotted for regeneration.

Cone production by individual longleaf pine trees is affected by site quality, stand density, tree size, and genetic predisposition (Croker and Boyer 1975). The best cone producers are dominant trees 15 inches or more in dbh, with large crowns and a history of past cone production. A tree 15 inches dbh will produce, on the average, more than twice as many cones as a 12-inch tree, and a 19-inch tree will produce more than twice as many cones as the 15-inch tree. Cone production per acre is affected by stand density and, on average sites, reaches a peak at densities between 30 and 40 square feet in basal area per acre and declines rapidly above and below this range (Croker and Boyer 1975). For a given stand density, per-acre cone production is not greatly affected by increasing tree size above 15 inches dbh because the increase in cone production per tree is offset by the reduction in trees per acre.

Cone production also varies considerably from year to year and from place to place. With an optimum number and quality of seed-bearing trees, the regionwide frequency of cone crops adequate for regeneration approaches 1 year in 3. Among observed locations, the frequency of acceptable cone crops ranged from zero to 3 years out of 4 over a period of 19 years (Boyer 1987). The frequency of good cone crops appears to be lower near the Gulf coast than farther inland. Because average cone production by longleaf pine varies so much by location, the expected frequency of usable cone crops must be based on local experience.

The dispersal range of longleaf seed is limited, with about 70 percent of sound seeds falling within 66 feet of the parent tree (Boyer and Peterson 1983). As a result, seed-producing trees must be distributed so that complete coverage of the regeneration area is ensured.

Pre-establishment Competition Control

Competition in the regeneration area, especially from hardwood trees and brush, must be controlled before seedling establishment. Longleaf pine, especially in the seedling stage, is very intolerant of competition from all sources. Competition on the ground may also constitute a barrier between dispersed seeds and the soil surface.

Well-Prepared Seedbed

Longleaf pine seeds require contact with mineral soil for satisfactory germination and establishment. The seeds, with their large wings, cannot easily penetrate a heavy ground cover of vegetation and litter, so this material must first be removed, either mechanically or by fire. Usually, a burn within 1 year prior to seedfall will provide an adequate seedbed (Croker and Boyer 1975).

Adequate Seeling Establishment

The criteria for successful regeneration depend on the landowner's requirements and management objectives. An accepted goal is a minimum of 500 well-distributed dominant seedlings per acre at a height (>3 feet) that is relatively safe from damage by fire (Croker and Boyer 1975). This goal requires a far larger number of newly established seedlings because of variable, but usually high, first-year mortality, followed by losses that accompany logging and periodic fires, and attrition from several common hazards.

Longleaf pine seeds germinate promptly after they are dispersed, often within 1 week under favorable conditions. Rapid germination reduces exposure to the many seed predators. Germinating seeds and newly established seedlings are vulnerable to insects and other animals, diseases, fire, and unfavorable weather such as drought, flooding, excessive heat or cold, and frost-heaving on heavy soils. Under good conditions, perhaps 20 percent of the sound seeds dispersed will become established seedlings (Croker 1975). The proportion of sound seeds that become established seedlings (tree percents) generally increases with seed crop size, averaging 3 percent with 20,000 seeds per acre and increasing to 26 percent with 100,000 seeds per acre. Large seed crops can satisfy seed predators, with enough seeds remaining to provide a good seedling stand.

Because the risk of seedling mortality is highest during the first year and much lower thereafter, regeneration success is based only on 1-year-old or older seedlings.

Adequate Seedling Survival and Growth

A number of factors can affect both the survival and growth of established longleaf pine seedlings. Seedlings are highly sensitive to competition from any source and are also susceptible to the brown-spot needle blight (*Scirrhia acicola* (Dearn.) Siggers); either factor can prolong the grass stage and may eventually destroy the seedling. At certain stages, longleaf seedlings are highly susceptible to fire damage. Seedlings also must be protected from livestock, especially hogs, which can rapidly destroy a grass-stage seedling stand (Lipscomb 1989). Grazing can remove the fuel needed to carry a fire for control of the brown-spot disease.

Fire--An established longleaf pine seedling stand must be protected from untimely, destructive fires. Fire risk is highest for suppressed seedlings under a pine overstory and remains so until nearly 2 years after overstory removal.

Grass-stage seedlings in the open become relatively resistant to fire damage when they reach a root-collar diameter of 0.3 inch and remain resistant until they initiate height growth. Longleaf seedlings of this size are fire resistant partly because they can sprout from the root collar if top-killed by a fire hotter than expected. Sprouting ability declines rapidly after seedlings begin height growth (Farrar 1975). The large, succulent foliage of longleaf also helps protect the bud and stem from heat injury in surface fires (Wahlenberg 1946).

Among longleaf pine seedlings of the same size (root-collar diameter), fire mortality of seedlings under a pine overstory is about double that of similar seedlings in the open (Croker and Boyer 1975). Within forest stands, healthy grass-stage seedlings that have reached 0.4 inch or more in root-collar diameter are relatively safe from mortality in carefully prescribed and executed winter fires (Boyer 1974a), even under parent overstories ranging up to 60 square feet in basal area per acre (Maple 1969). Some fire resistance is lost during the early stages of height growth, until seedlings reach a height of 2 to 3 feet, after which they again become less vulnerable to fire kill (Maple 1975).

Brown spot--Brown-spot needle blight is the worst disease afflicting grass-stage longleaf pine seedlings and is likely to intensify rapidly in a seedling stand after the parent overstory is removed. Fire is the cultural treatment used to control this disease in natural seedling stands and may be prescribed for this purpose, depending on disease status derived from surveys of dominant seedlings in the stand. Once seedlings are heavily infected with brown spot, they are at increased risk of loss, not only from the disease but also from fire. Instead of protecting the seedling from fire, the foliage adds to the fuel load. Brown spot is unlikely to reach serious levels in seedling stands retained under a pine overstory (Boyer and Peterson 1983), even at densities as low as 9 square feet in basal area per acre (Boyer 1975). As a result, these seedling stands need not be burned before reaching a fire-resistant size.

About 10 to 20 percent of a natural seedling stand will normally exhibit resistance to brown spot (Boyer 1972). Vigorous, brown-spot resistant individuals express early dominance. This dominance results in a rapid breakup of the seedling stand into a range of size classes that persists for years (Boyer 1972), reducing the risk of stagnation and normally eliminating any need for precommercial thinning.

Competition--Elimination of all competition in a regeneration area is not practical, but an established seedling stand should be free from most overtopping vegetation. If the woody midstory and understory vegetation is largely eliminated before seedling establishment, only the pine overstory and herbaceous vegetation on the forest floor remain as major competitors with a newly established seedling stand. Mature pines will retard seedling growth up to a distance of at least 55 feet, although degree of suppression diminishes with distance (Boyer 1963). Longleaf seedlings can survive under a parent pine overstory for at least 8 years and probably longer if they are not burned before reaching a fire-resistant size (Boyer 1963). Seedling growth, however, is very slow, and seedlings take a long time to reach a fire-resistant size, depending on density of both overstory and understory competition. Once the overstory is removed, seedlings respond quickly and will rapidly occupy the released growing space.

NATURAL REGENERATION METHODS

Natural regeneration methods suited to longleaf pine are limited. Longleaf is a very intolerant species that usually is established as an even-aged stand by one of the infrequent large seed crops. Neither the clearcutting nor the seed-tree method of natural regeneration is effective for longleaf (Croker and Boyer 1975). Clearcutting a mature stand will destroy most advanced reproduction, if present, and the short seed dispersal range limits seeding from adjacent stands. Except in a low- to medium-density stand well-stocked with advanced reproduction, clearcutting must be followed by some form of artificial regeneration. A seed-tree method, leaving 5 to 10 residual trees per acre after harvest, is a high-risk regeneration method for longleaf, unless the cutting coincides with a heavy seed crop. A seed-tree stand produces only a fraction of the seed produced by a shelterwood stand, so the frequency of adequate seed crops is much lower. During the wait for a good seed crop, growing space is quickly occupied by hardwoods and brush, resulting in rapidly increasing costs for seedbed preparation and competition control. Some examples of successful regeneration in nature resemble the shelterwood system and led Croker (1956) to the hypothesis that this method is the most appropriate for longleaf pine. This hypothesis has since proven to be the case. The shelterwood method is highly flexible and can be adapted to a wide variety of site conditions and management objectives.

APPLYING THE SHELTERWOOD SYSTEM

The two principal variants of the shelterwood system applied to longleaf pine are the three-cut and the two-cut methods. They are identical, except that the three-cut method has a preparatory cut which precedes the seed cut. A well-managed longleaf pine stand periodically thinned to medium densities will not need a preparatory cut, so the regeneration process can begin with the seed cut. Planned regeneration of an unmanaged stand or a stand with overstory pine densities greater than 80 square feet in basal area per acre may need a preparatory cut. Guidelines for application of the shelterwood system of longleaf pine natural regeneration have been reported by Croker and Boyer (1975), and Boyer (1979a).

The three-cut shelterwood method is typically applied as follows:

The Preparatory Cut

The preparatory cut is made 10 or more years before the planned harvest date of the stand at rotation end and at least 5 years before the seed cut. Stand density is reduced to a maximum of 60 to 70 square feet in basal area per acre of dominant and codominant longleaf pines, depending on site quality. If gaps exist in the stand, the overall average density of the residuals will be somewhat less. This cut promotes crown development and thus cone production. At this time, most hardwoods too large for control by fire should be harvested, if merchantable, or cut down. The regular use of prescribed fire during the rotation should have resulted in an understory with little hardwoods and brush. If a large number of small woody stems are present, a series of annual or biennial growing season burns may be necessary to reduce this component of the understory. This control must be completed before the seed cut, while needle litter accumulation is sufficient to fuel hot surface fires and before a seedling stand has been established.

The Seed Cut

The seed cut is made 5 years before the planned harvest to leave a density not exceeding 30 square feet in basal area per acre of high-quality dominant trees with well-developed crowns. Trees with some evidence of past cone production are favored. The density goal is not an average of 30 square feet, because this density might result in leaving 60 square feet in one location to compensate for a hole in another. Although cone production per acre peaks in the range of 30 to 40 square feet in basal area per acre, the lower end of the range is preferred, because logging-related seedling losses increase with increasing density of the overstory removed (Maple 1977a). The dominant trees in the shelterwood stand will capture some of the released growing space so that even when stand density has been halved by the seed cut, merchantable volume growth is reduced only about 30 percent (Farrar 1985). The reduction in volume growth over a 5 year regeneration period is not great, and when the value growth on high-quality residuals is considered, the economic loss is less than the growth reduction alone suggests.

A shelterwood stand still produces enough needle litter to continue prescribed burning with surface fires hot enough to check hardwood encroachment. The stand also is dense enough to slow the growth of understory hardwoods, preventing them from reaching a fire-resistant size during a 2- to 4-year interval between burns.

Per-acre mortality among overstory pines remains about the same after the seed cut as it was before. Long-term observations indicate an average annual mortality of one tree per 2.5 acres, although half of observed stands averaged less than one tree per 5 acres (Boyer 1979b).

Cone Crop Monitoring

Any good seed crop following the seed cut must be used. Estimates of cone crop size are made in advance by annual spring binocular counts of both flowers and 1-year-old conelets on selected sample trees in the regeneration area. These counts permit anticipation of cone crops potentially large enough to regenerate the stand so that cultural treatments for seedbed preparation can be carried out before cones open.

Binocular counts are made when both flowers (next year's cone crop) and 1-year-old conelets (this year's cone crop) are most visible (Croker 1971). This period is a relatively short time (2 to 3 weeks) in April or May, before flowers are obscured by developing foliage but after enlarging conelets are easily seen in last year's foliage. Counts are used to estimate cone crop size for the next 2 years. Flower counts are unreliable predictors of cone crop size because of highly variable losses during the first year, but they do reliably predict cone crop failures. Conelet counts are fairly good predictors of cone crop size for the coming fall.

Seedbed Preparation

Assuming that most woody vegetation has been controlled, a prescribed burn within 1 year prior to seedfall should be all that is needed to remove accumulated litter and expose sufficient mineral soil for seedling establishment. If a winter seedbed burn is desired, it will be based on predictions from the more unreliable flower counts. A seedbed burn based on spring conelet counts can be done as soon as scheduling and conditions permit. A late spring burn is more effective in controlling residual woody stems. A late summer or fall burn before seedfall will provide an adequate seedbed for two successive cone crops if these crops are in prospect. However, a burn at this time of year is more likely to damage or destroy any longleaf seedlings and saplings already present in the regeneration area and may kill some of the mature trees (Boyer 1990b). Late summer burns often result in increased predation of longleaf seeds because of lack of a light, protective ground cover and destruction of alternative foods.

If for some reason a prescribed fire cannot be used to prepare a seedbed, a mechanical treatment to expose mineral soil may be necessary. The combination of fire with a mechanical treatment should improve seedling establishment, but the increased cost may not be justified unless the cone crop is marginal, or unless additional control of woody vegetation is required. Some mechanical treatments will damage the root systems of mature trees.

Regeneration Survey

Regeneration surveys are carried out before the seed cut to determine the status of longleaf pine reproduction already on the site. If some regeneration is present, another survey is taken 1 year after the seed cut. This period gives logging slash time to decay and allows damaged seedlings time to recover or die. The status of regeneration is then monitored through annual surveys.

The regeneration area may consist of differing forest cover types or a diversity of overstory and understory conditions. If so, it is best to stratify the area into relatively homogeneous units, with a separate survey for each. A common separation is that between longleaf pine upland and hardwood or pine-hardwood creek bottoms. The latter would not be included in the regeneration area. The upland itself may be stratified into units based on overstory or understory conditions that are expected to affect cone production or seedling establishment. In practice, regeneration areas usually are so small (<100 acres) that stratification of the upland is not necessary. Regeneration surveys are made in the dormant season when green grass-stage seedlings are easy to see. Grass and other herbaceous vegetation will obscure small longleaf seedlings during the growing season, making them very hard to find.

Information obtained by the survey includes:

1. The proportion of sample plots stocked with one or more seedlings;

2. Size of the best seedling in each stocked sample plot, namely root-collar diameter and height, if any, to base of terminal bud; and

3. Severity of brown-spot infection on the best seedling in each sample plot.

The above data will provide information on seedling survivability, especially if the area must be burned for seedbed preparation, competition control, or control of brown-spot needle blight.

The regeneration goal is 6,000 or more seedlings per acre at least 1 year old before the parent overstory is removed (Boyer 1979a). This number allows for logging losses of up to 50 percent of the seedling stand and still leaves enough survivors so that the superior, fast-growing,brown-spot-resistant fraction will provide 300 to 600 well-distributed dominant trees per acre. The stocking of quarter-milacre plots is a sensitive index for stands of 4,000 to 8,000 seedlings per acre, because of the relationship between stocking percent and seedlings per acre (Boyer 1977). Sixty-three percent of sample plots stocked with seedlings is equivalent to 6,000 seedlings per acre.

The goal of 6,000 seedlings per acre is not inflexible and may have to be adjusted downward because of local conditions. Some locations have a low frequency of good seed crops, so the chance of reaching the goal within a reasonable regeneration period is poor. The number, size, and distribution of seed trees also may limit chances of reaching the goal. However, the regeneration goal can be reduced by at least one-half and still retain a high probability of obtaining 500 well-distributed dominant trees per acre, particularly if logging losses are minimized through careful supervision. The manager may decide to accept an established seedling stand as low as 2,000 per acre, especially if final harvest is due and no seed crops are in prospect. If an inadequate seedling stand survives logging over all or part of the regeneration area, the artificial regeneration option is still available. Because small longleaf pine seedlings (<0.4-inch root-collar diameter) need protection from fire, regular burning in the regeneration area should be discontinued after a good seedling stand is established. Seedlings under a shelterwood overstory remain vulnerable to fire damage for some time because of their slow growth and the accumulated needle litter fuel, particularly under the crowns of parent trees. Under these conditions, fire should be prescribed only for a necessary objective (seedbed preparation or competition control), with due regard for expected seedling mortality.

The Removal Cut

Once an acceptable seedling stand is present, the parent overstory can be removed. If all activities have gone according to plan, the harvest cut is made on schedule. However, this cut can be delayed, if necessary, for management needs or market conditions. Seedlings can survive 8 or more years under a parent overstory with no effect on survival, provided the stand is not burned. However, seedling growth will be slow. When compared with a seedling stand released from overstory competition at age 1, a shelterwood overstory of 30 square feet in basal area per acre will account for 70 percent of the growth loss observed under overstory densities of 90 square feet in basal area per acre (Boyer 1963).

The best time to remove the parent overstory, in terms of seedling loss, is at seedling age 1 or 2. Logging-related mortality at this time has averaged 35 to 40 percent (Boyer 1974b). By age 3 to 5, seedling mortality has increased to 50 to 55 percent with overstory removal. Seedling mortality also increases with increasing density of the parent overstory (Maple 1977a), from 42 percent with removal of 20 square feet in basal area per acre, 54 percent with 40 square feet, and 69 percent with 60 square feet. If overstory density is 40 square feet or more in basal area per acre, the overstory is removed in two cuts rather than one. This method reduces the load of logging slash on the ground at any one time, and additional seedlings may be established between cuts. Logging damage becomes more serious once seedling height growth begins. Stemless grass-stage seedlings are less likely to suffer serious damage, and even when they do, usually are able to sprout.

Postharvest Treatments

After overstory removal, the principal factors affecting seedling development are competition intensity and brown-spot needle blight. Prescribed fire is the most common cultural treatment used to control brown spot and to slow the development of competing woody vegetation. Timing of the burns is critical, because mistimed fires can do more harm than good. The need for a burn must be carefully evaluated in advance and both the potential benefits and the possible damage to the seedling stand must be considered. Regeneration areas should not be burned until at least two years after the removal cut because of the excessive fuel load and the vulnerability to fire of small, suppressed seedlings. Two years allows enough time for both the logging slash and accumulated pine needle litter to decay and the seedlings to respond to release.

The need for a brown-spot burn must be determined from a survey that carefully evaluates seedling condition and the distribution and severity of the disease. Status of the disease must be determined based on the best dominant, or "crop," seedlings rather than on average seedlings in the stand (Croker 1967).

Brown-spot surveys are conducted during the dormant season as part of the regeneration survey described earlier. The crop seedling on each stocked sample plot is identified based on size, vigor, and freedom from brown spot. Root-collar diameter, height, and amount of the current year's foliage destroyed by brown spot (estimated to the nearest 10 percent) are recorded. Nature and condition of fuels in the regeneration area also are noted. The decision to burn is made using this information; it depends on the severity of the disease and the expected mortality among crop seedlings from a cool winter fire. If average brown-spot infection on sampled seedlings exceeds 20 percent, a burn is needed to control the disease, if the burn does not produce excessive mortality. The burn can be made in the winter or spring following the survey. Seedlings in the early stages of height growth are most susceptible to fire kill, especially if they are heavily infected with brown spot. Mortality risk for individual longleaf pine seedlings subjected to a winter fire can be estimated based on seedling height and percent of foliage killed by brown spot (Maple 1976). Because 10 percent or more of the stand should be resistant to brown spot (Boyer 1972), most crop seedlings may remain relatively free of the disease. In this case a fire need not be prescribed for brown-spot control.

After longleaf seedlings are released from competing vegetation, early development accelerates, shortening the period that seedlings will be vulnerable to mortality from either periodic prescribed fires or severe brown-spot infection. On the average, it takes 3 years after overstory removal for brown spot to reach a growth-retarding intensity in a seedling stand (Boyer 1975). If crop seedlings reach a disease-resistant size by this time, a serious brown-spot problem is avoided.

Understory hardwoods can be controlled with periodic prescribed fires. Burns in the spring (May) seem more effective in controlling woody competition than those at other times and also appear to accelerate initiation of height growth by longleaf seedlings compared with similar seedlings burned in the winter or not burned at all (Grelen 1978, Maple 1977b).

After the final removal cut, if a large number of fire-resistant woody stems still are present in the regeneration area and are overtopping and suppressing pine seedlings, a release treatment may be necessary by cutting and/or using a herbicide registered for this purpose. The cost of such treatments is high, but can be justified if it is needed to ensure survival and eventual dominance of the pines. Again, woody competition in the regeneration area should be controlled before the seedling stand is established. Prescribed fire at 2 to 4 year intervals during the rotation is the most cost-effective method to attain this goal.

MODIFICATIONS OF THE SHELTERWOOD SYSTEM

The shelterwood method of longleaf pine natural regeneration, described above, can be applied in three different ways--block, progressive strip, and group--although there are gradations among these.

Block

Blocks are associated with the establishment and management of even-aged stands. The block is most likely to be a forest stand approaching rotation age that has been identified as a management unit. Block size can vary considerably. Most blocks will fall between 10 and 100 acres, although some are considerably larger. The area normally is enclosed, to the extent possible, within natural and artificial boundaries, such as roads and creek or river bottoms. This enclosure will minimize the length of artificial firebreaks that must be constructed and maintained, as the block also will constitute a burning unit.

Progressive Strip

The progressive strip shelterwood aims to produce and maintain a range of age classes, from seedling to mature stand, within a larger management unit. Thus, completion of the cutting cycle will cover a rotation rather than a short span of years. Strips are long and narrow, not exceeding 200 feet in width, so that most or all of the strip will be within seeding range of adjacent timber. Strip edges need not be straight but can meander to fit the terrain. Strips should progress against the prevailing winds to facilitate seed dispersal into recently cleared strips. As the seed cut is made on the first strip, the preparatory cut is made on the next. If a seedling stand has been established on the first strip, at the next entry the overstory is removed. At the same time, a seed cut is made on the second strip and a preparatory cut on the third. Any gaps or holes in the first strip from logging damage can be seeded from trees on the second strip. Strips progress across the larger management unit. When the removal cut is made on the last strip, it is time to make the seed cut on the first strip, completing the rotation. If thinnings are made periodically throughout the unit, the two-cut method is applicable.

Group

Group or "patch" shelterwood describes regeneration areas too small to be considered blocks. The breakpoint in size between block and patch is rather broad and open to interpretation. The principal difference is that the block is a large management unit containing one age class, with much of the boundary based on natural or physical features or property lines. Patches begin as small regeneration areas within a larger area that is considered the management unit. As in the strip shelterwood, patches are created and regenerated over time so that a full range of age classes eventually is obtained within the larger unit. The shelterwood method is applied to patches in the same manner as strips or blocks. At each entry, new patches can be created, old ones enlarged, or both. In practice, patches initially are likely to range from 0.5 to 5 acres. If patches are enlarged by successive cuttings, they may come to resemble irregular strip cuttings.

Group or patch shelterwood regeneration is a technique appplicable to either even-aged or uneven-aged management by the group-selection method. In the former, the even-aged stands created in patches are identified and mapped on the ground and followed through time; in the latter, the entire management unit is treated as a whole, with no formal consideration given to the various age or size classes within the unit. Cutting is regulated by volume or stand structure (diameter distribution) control. The uneven-aged management option is favored because of the difficulty and cost of prescribing and applying cultural treatments and cuttings to, and maintaining records on, a large number of widely scattered small patches of varying ages.

Management Considerations

The easiest and most efficient management method for longleaf pine is a block comprising an entire, easily identifiable management unit within which an even-aged stand is created and maintained. This approach has been almost universally applied to the species. Examples of strip or patch shelterwood are rare. Strip or patch cutting in longleaf pine would be most applicable to small holdings in which the owner wants all age classes equally represented to obtain a fairly even flow of income and expenses over time. The patch shelterwood method of regeneration also applies to those who wish to keep the size of clearings small or to develop the group-selection method of uneven-aged management for their forest.

The principal disadvantage of patch shelterwood for longleaf pine is the exposure of seedlings and saplings to prolonged suppression from adjacent older stands. Competition from a wall of mature timber may extend 55 to 70 feet into an opening and can affect most or all of the seedlings in a clearing, depending on its size. If the competition zone is 55 feet, 72 percent of a circular 1-acre opening is exposed to competition from the side, as is 37 percent of a similar 5-acre opening. Some experience indicates that this type of management results in substantially less volume growth than that expected from uniform even-aged stands under similar conditions of site, stand density and rotation length (Boyer and Farrar 1981, Farrar 1985, Farrar and Boyer 1991). However, if the landowner's management objectives include creation and maintenance of the uneven-aged condition for the forest, the change in structure and appearance generated by patch cuttings may compensate for reductions in volume growth.

Both strip and patch shelterwoods complicate the use of prescribed fire, the principal cultural treatment in longleaf management. Needs differ with stand age. While a shelterwood stand may need a seedbed burn, a seedling stand just beginning height growth may need protection from fire. Confining a burn to a single strip is costly, because of the fireline length per unit area to be burned. With patch cutting, attempts to burn, or protect from fire, any single age class is not possible because each age class occupies a number of small areas widely dispersed throughout the management unit. The manager can only adjust the timing and execution of periodic prescribed fires to accomplish priority objectives with minimum impact on the more fire-susceptible size classes. The general resistance of longleaf pine to fire damage throughout most of its life cycle, and the breakup of a single age class into a range of size classes, should result in minimal damage from careful prescribed fires.

CONCLUSIONS

Natural regeneration of longleaf pine is a low-cost alternative wherever there is an existing longleaf stand with sufficient seed-producing trees. This approach has the advantage of retaining and using genetic material that has successfully adapted to local conditions over thousands of years. The shelterwood method of regeneration seems best suited to the habits and requirements of this species and ensures that an adequate seedling stand is established before the parent stand is cut. The approach can be adapted to meet a variety of management objectives and is especially applicable for the landowner who does not wish to make a large investment for site preparation and planting after the mature stand is removed. Successful application of the method always requires careful advance planning, regular monitoring of conditions in the regeneration area, and proper timing and execution of all necessary cultural treatments.

The shelterwood system has been successfully used to regenerate longleaf pine for more than 30 years, covering a range of geographic locations and site conditions. If, for lack of an adequate seed crop or for other reasons, natural regeneration is not possible, the artificial regeneration option is always available.

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