Natural Reproduction Methods for Hardwood Regeneration

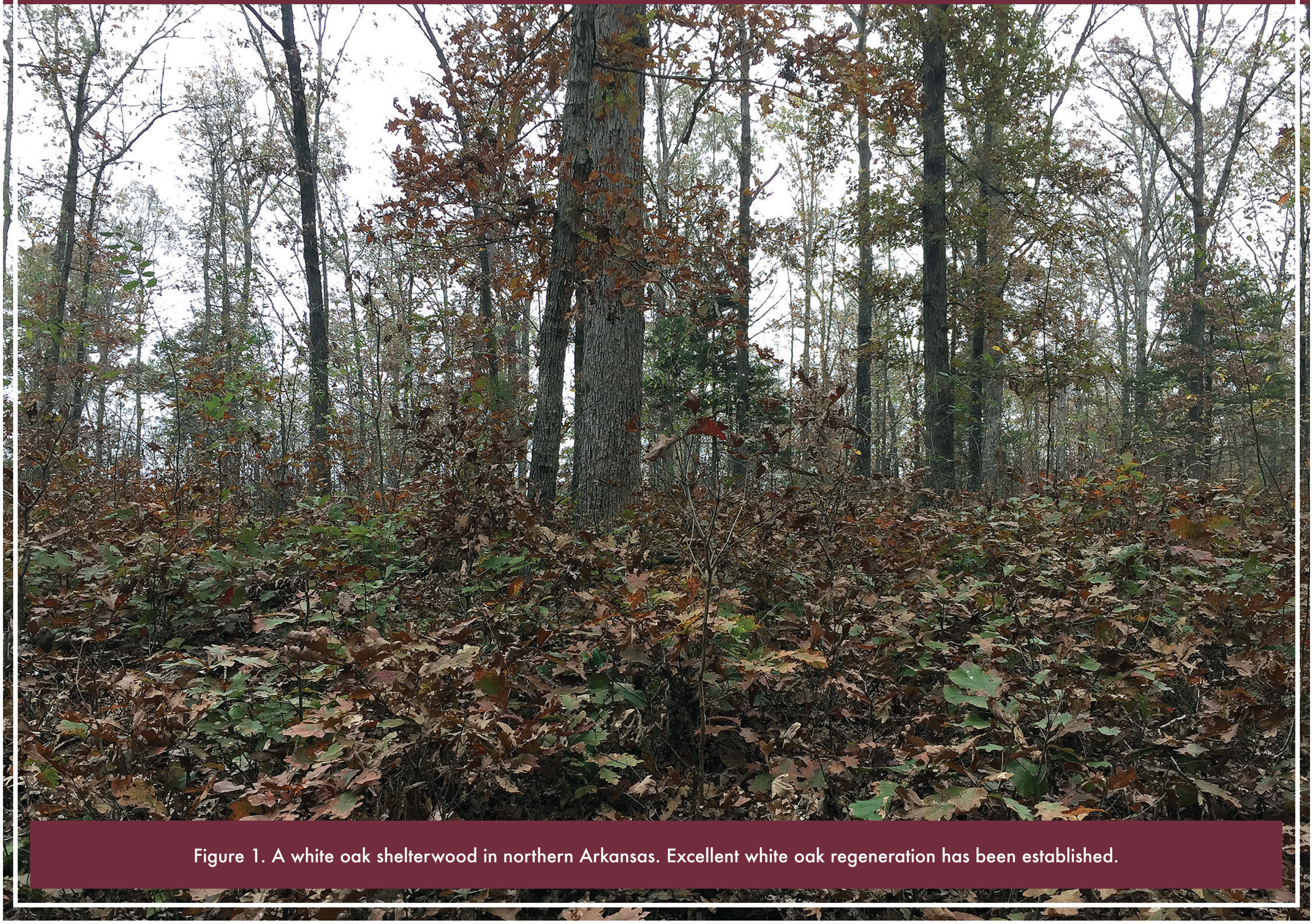

Figure 1. A white oak shelterwood in northern Arkansas. Excellent white oak regeneration has been established.

Introduction

Some of the more common points of confusion in regenerating hardwood stands center around a lack of knowledge regarding silvicultural systems and methods. While sometimes considered unimportant, an understanding of what a silvicultural system is ensures that forest managers are on similar standing when prescribing management techniques. Various silvicultural systems and reproduction methods should be defined so that effects of their implementation are not unexpected and result in achievement of desired management goals (Figure 1).

A silvicultural system is a planned program of silvicultural treatments extending throughout the life of a stand, including regeneration, intermediate treatments, and whatever protection measures are appropriate (Ashton and Kelty 2018). A reproduction method is the procedure through which a stand is established. Reproduction methods fall into one of three categories: even-aged, two-aged, or uneven-aged.

Even-aged methods are designed to regenerate a stand with reproduction of the same age class (seedlings are established within 20 percent or less of the rotation length). Even-aged methods (clear-cut, seed-tree, and shelterwood) are considered the most successful for regenerating hardwood stands due to the greater knowledge and experience of stand development associated with these methods. The two-aged method results in stands with two age classes. Uneven-aged reproduction methods regenerate stands with at least three age classes. They (single-tree and group selection) have a history of misuse and are often discouraged in hardwood management as management of shade-intolerant species like oak is complicated and difficult to achieve. However, increasingly, attention is being given to uneven-aged methodology as knowledge of the practices is obtained. The following sections provide descriptions of each reproduction method along with application and variation applicable to hardwood management.

Clear-Cut Method

Overview

The clear-cut reproduction method involves removal of all trees in a stand in one harvesting operation (Figure 2). Future natural regeneration will either be from seed buried in or lying on the forest floor before harvest or from seed deposited onsite after harvesting (Ashton and Kelty 2018). Regeneration occurring from advance regeneration (1- to 4-foot-tall seedlings with well-established root systems existing before harvest) is considered a product of the shelterwood method, while root and stump sprouts are considered products of the coppice method (both described later). Regardless of the form of regeneration, the new stand will be even-aged and will undergo canopy stratification over the first 10 to 20 years of the new stand's rotation. Ecologically speaking, clear-cutting is a major disturbance and closely mimics major wind events such as a hurricanes and large tornadoes. Of course, there are differences with clear-cuts, including a lack of the pit/mound topography associated with windthrown trees, absence of tree boles due to utilization, and the lack of snags from trees snapped by wind.

Clear-cutting favors development of shade intolerant, light-seeded species that require bare mineral soil for germination (such as eastern cottonwood, black willow, American sycamore, green ash, and yellow-poplar).

Figure 2. A clear-cut in northern Mississippi.

Moderately shade-tolerant and shade-tolerant species can become established before harvest. These include the oaks, hickories, ashes, maples, elms, beech, and other shade-tolerant species. These species are favored by clear-cutting if present as large advance regeneration before harvest.

The clear-cut reproduction method is a simple operation. In general, two types of clearcuts are recognized. Complete clearcuts involve felling all trees greater than 1 inch in diameter at breast height (DBH) (diameter at 4.5 feet above ground level). Full sunlight, as well as a complete lack of competition for water and nutrients, are available to the new, developing vegetation. Commercial clearcuts involve removal of only merchantable trees. Without instruction, logging contractors often leave trees of poor form, unmarketable species, or outside the limits of merchantability standing on site. While commercial clearcuts have greater vertical and horizontal structure compared to complete clearcuts, residual stems interfere with development of desirable regeneration. Often, these residual trees are controlled during chemical site preparation, or are felled by logging equipment during harvesting.

Advantages of the clear-cutting method

- In some instances, clear-cutting has proven successful in regenerating hardwoods (Meadows and Stanturf 1997).
- Clear-cutting can maximize short-term economic returns.
- Clear-cutting provides the sunlight required for growth and development of moderately shade-intolerant to shade-intolerant species.
- Clear-cutting aids tree development through the effects of desirable competition.
- Clear-cutting favors early successional plant and animal species.
- Clear-cutting may improve water quality through enhanced sediment deposition (Zaebst et al. 1995).

Disadvantages of the clear-cutting method

- Clear-cutting causes a decrease in horizontal and vertical structure for wildlife.
- Clear-cutting creates a lack of aesthetically pleasing appearance.
- Clear-cutting offers erratic results in obtaining adequate desirable natural postharvest regeneration.
- Clear-cutting leaves no provision for natural regeneration in the event of seedling crop failure.
- Clear-cutting creates a lack of hard mast production for at least 20 years.
- Thirty to 40 years must pass before trees are large enough for economic returns.
- Clear-cutting displaces wildlife that require mature stand conditions.

Application

While often not appropriate, the clear-cut method is the most widely used method of regenerating hardwood stands. Typically, no provision is made for ensuring adequate sources of regeneration before harvesting. However, when implemented carefully, the method can be successful in regenerating many hardwood species.

Using the clear-cut reproduction method to favor light-seeded species like eastern cottonwood or black willow is risky because floodwaters or wind are required for seed distribution from adjacent or faraway sources. Success has been achieved using clear-cutting along with intensive site preparation to remove all down coarse woody debris in eastern cottonwood regeneration efforts. This is needed to maximize bare mineral soil exposure for eastern cottonwood seed germination and seedling development. Floodwaters are necessary, yet unpredictable, for distributing eastern cottonwood seed and for depositing silt, although seed viability becomes limited during prolonged flooding.

Floodwater can also disseminate green ash and American sycamore seed in some systems, but clear-cutting for regeneration of these species is more reliable. Both species can regenerate via advance regeneration, as well as from stump sprouting or wind dissemination. In all cases, preharvest regeneration evaluations should be conducted to determine if adequate stocking or sprouting potential is present before harvest.

If yellow poplar is desired, the clear-cut reproduction method has been observed to work well. Obviously, yellow poplar must be present in the overstory before harvesting. If present, an adequate supply of seed is usually buried in the forest floor and remains viable for up to 7 years (Clark and Boyce 1964). Harvesting scarifies the forest floor exposing mineral soil needed for yellow poplar germination.

The clear-cut reproduction method can also be used to regenerate heavy-seeded species, such as the oaks and hickories. However, it is extremely important that a regeneration evaluation is conducted before harvesting to determine if adequate stocking of desired species is present. If desired stocking is present, then a clear-cut operation may be considered. Harvesting should occur during dormant season months (November through early March) when dry conditions are present. This allows for maximized sprouting potential and the best chance to utilize the current year's seed crop (Kellison et al. 1981). Ideally, mechanical shearing of residual stems after clear-cutting will give best results. The operation cuts all residual stems at the ground, encouraging stump sprouting. If harvesting is conducted during the growing season, sprouting potential will be reduced as stored food reserves in the root system will be at a minimum.

If adequate advance reproduction is not present, steps must be taken to establish and develop this regeneration before harvesting. Steps in this process may include:

- Waiting until advance regeneration becomes established and/or develops to an appropriate size before harvesting;
- Reduction of competition, especially if midstory, shade-tolerant species are present; or
- Planting desired species in a supplemental planting operation.

The clear-cut reproduction method may also be necessary for severely degraded stands that underwent diameter-limit/high-grading operations in the past. High-grading is a practice where the highest value trees are removed, leaving only inferior trees without regard for future development or species composition. In these stands, managers may find that starting over, by clear-cutting and planting, is the most efficient means of regeneration (Allen et al. 2001). For a more thorough explanation of diameter-limit cutting/high-grading, please refer to Mississippi State University Extension Publication 3451, *What Is High-Grading?*.

Variations

Patch Clear-Cut Method

Most clear-cutting operations could correctly be classified as block clear-cutting where the size and boundaries of the harvest area are based on ownership or management boundaries. Opening sizes typically range from small to cuts encompassing several hundred acres, although there is no biological limit to maximum size of a clear-cut.

Figure 3. Patch clear-cut established for creation of wildlife habitat.

Figure 4. A strip clear-cut on the Yale-Myers School Forest, Windham County, Connecticut. The strip is oriented east to west to take advantage of full sunlight conditions.

Figure 5. Acorns on branches of felled oak. These acorns are mature and could provide seed for regeneration of a fresh clear-cut. (Photo courtesy of Pierce Young, private lands biologist, Mississippi Department of Wildlife, Fisheries, and Parks)

Patch clear-cutting differs and places limits on opening size. Typically, openings of 2 to 7 acres are created. (Figure 3). Smaller clear-cut sizes maintain the conditions necessary for regeneration of shade-intolerant species while maintaining a forest for landowners that do not desire cutting entire stands for aesthetic purposes. In addition, wildlife management efforts often utilize this method for creation of habitat for various wildlife species. Another advantage associated with patch clear-cutting is that irregular boundaries can be created more easily. A disadvantage is the increased management and logging costs associated with having to create and track multiple patches.

Strip Clear-Cut Method

Strip clear-cutting involves alternating strips/corridors of harvested and unharvested or thinned trees within a stand (Figure 4). The method provides the same aesthetic and habitat creating benefits of patch clear-cutting while simplifying logging operations and reducing costs. The method has not been utilized to a large extent in Southern hardwood silviculture but has shown promise in research.

Seeds-in-Place Method

The seeds-in-place method relies on seed falling before harvest or seed dispersal from trees felled during harvesting (Figure 5). This method requires knowledge of seed maturity of species targeted for regeneration and the ability to time of harvesting operations to coincide. This often proves difficult or uncertain, and the method is rarely used in Southern hardwood silviculture.

Seed-Tree Method

Overview

The seed-tree reproduction method involves leaving a few well-distributed trees of desirable species per acre (usually between five and 10) after harvesting operations. Seed-tree cutting can work with light-seeded species but has been less successful with heavier seeded species like oaks. The method involves three stages. Trees intended to serve as seed sources should be selected and monitored 5 to 10 years before any cutting operation. This allows the manager to select the best specimens for future seed production. Selected trees should have characteristics of good potential seed production such as well-developed, vigorous crowns and evidence of past seed production. If the stand has been thinned before, then preparatory work may be unnecessary as potential seed trees may be obvious. After selections are made, all other trees are removed except for seed trees (Figure 6). After successful regeneration, seed trees are then removed to allow development of regeneration into an even-aged stand. It may be necessary to control competing, shade-tolerant stems through midstory injection before removal of non-seed trees. For more information on midstory injection in hardwood stands, please consult Mississippi State University Extension Publication 2942, *Tree Injection for Timber Stand Improvement*.

Only slightly less intense than the clear-cut method, the seed-tree reproduction method is a major disturbance that imitates stands devastated by fire or wind, where a few scattered residual trees are left. As with clear-cutting, differences between seed-tree cutting and a natural disturbance include removal of tree boles from the stand, a lack of pit/mound topography, and an absence of snags.

The seed-tree reproduction method is correctly employed when used for light-seeded species that use wind seed dissemination. Seed crop potential can be checked by periodically using binoculars to observe developing seed, or by obtaining branches containing flowers or seed. If a good seed crop is detected, then site preparation treatments can be conducted before seedfall to prepare the seedbed. If a poor seed crop is detected or if an insufficient number of seedlings are established, then seed trees can be left as a seed source for the next few years. Additional site preparation may be necessary to maintain acceptable seedbed conditions, but these treatments can be delayed until an adequate seed crop is detected.

Advantages of the seed-tree method

- Trees left to regenerate the area are of the best appearance and assumed genetics.
- Seed-tree cutting is more aesthetically pleasing compared to clear-cutting to some.
- The seed tree reproduction method promotes early successional plant and animal species, which is favorable to wildlife habitat creation for some species.

Disadvantages of the seed-tree method

- Seed trees may develop epicormic branches after initial harvest, which may result in a substantial loss of economic value.
- Seed trees are more susceptible to windthrow and lightning damage.
- The clear-cut reproduction method often exhibits similar regeneration results.
- Wildlife species that require dense, mature forest conditions may be displaced.

Figure 6. Seed-tree cutting establishment in a stand of loblolly pine. Even though residual pine density is low, approximately half of these trees would be cut to bring overall stem density down to a level appropriate for correct seed-tree stocking.

Application

In general, using the seed-tree method to regenerate bottomland hardwood forests is not considered feasible (Clatterbuck and Meadows 1993; Kellison and Young 1997). With only a few trees left after initial harvest, forest floor conditions are essentially the same as a clear-cut. Seed of light-seeded species (eastern cottonwood, black willow, and American sycamore) is distributed long distances by wind and water from adjacent stands. Some light-seeded species, such as sweetgum, readily regenerate from root and stump sprouts, and soil-banked seed of species like yellow poplar can remain viable for several years. Seed trees are considered ineffective in regenerating heavy-seeded species, such as oaks and hickories. These species are regenerated primarily through advance regeneration established before initial harvest. Seed dissemination of these species in seed-tree harvesting is very short and achieved through gravity, small mammals, birds, and sometimes water. Therefore, more trees are necessary for adequate distribution of seed to cover a stand after regeneration efforts begin.

Shelterwoods Method

Overview

The shelterwood reproduction method involves removal of trees in a series of partial harvesting operations to establish advance regeneration under the shade of existing overstory trees (Figure 7). A textbook installment of the shelterwood reproduction method involves a minimum of three harvesting operations. The first operation is called a preparatory cut, in which selected trees are retained for their potential seed production capabilities. Removal of competing trees from lower crown classes helps provide the light necessary for establishment and development of regeneration after the second harvesting operation. In addition, diseased, or otherwise unhealthy, undesirable, or problematic trees may also be removed during this cut. Removal of selected overstory trees encourages crown growth and helps promote wind firmness of the stand. Midstory stems that block sunlight from reaching the forest floor are often chemically treated at this stage as well. In reality, preparatory cuts are often not employed due to economic considerations and the operation is performed simultaneously with the next cut.

The second operation, conducted several years later, is called the seed cut. In the seed cut, trees are left to produce seed and provide shade for developing regeneration. For oak species, research has shown that a suitable range of basal area capable of producing advance regeneration after a seed cut is between 40 and 60 square feet of basal area per acre. Maximum regeneration typically occurs at 50 square feet.

Figure 7. An oak forest that has undergone the seed-cut stage of a shelterwood. Overstory trees have been removed leaving a targeted basal area of 50 square feet to establish advance regeneration.

Consequently, most forest managers use this as their target basal area in seed cuts. The final operation is the removal cut, in which seed trees are removed and a new even-aged stand is regenerated. For more information on regenerating hardwood stands using the shelterwood reproduction method, please consult Mississippi State University Extension Publication 3461, *Bottomland Hardwoods: Natural Regeneration Using the Shelterwood System*.

The ecological counterpart to the shelterwood method is either a mild windstorm in which a few overstory trees are downed or a moderate wildfire that removes much of the understory and midstory but kills only a small portion of the overstory trees. Use of the shelterwood method may either set back or promote succession. A heavy seed cut (leaving only a few overstory trees) will promote shade-intolerant species, thereby setting succession back. A light seed cut, in which many overstory trees are left, will provide heavy shade on the forest floor and promote regeneration of shade-tolerant species thereby promoting succession.

Advantages of the shelterwood method

- Greater numbers of residual trees after the seeding cut increase the amount of seed reaching the forest floor compared to the seed-tree method.
- The method provides increased structure and diversity for wildlife habitat.
- It is considered the most aesthetically pleasing even-aged regeneration method.
- Unlike clear-cut and seed-tree methods, shelterwoods can promote forest succession to a later stage.

Disadvantages of the shelterwood method

- The increased number of harvesting operations may result in damage to the site, especially if conducted during wet conditions.
- Log grade may be decreased for seed trees that develop epicormic branches during the shelterwood process, thereby losing economic value.
- The risk of loss to windthrow is increased.
- If care is not taken, it may be difficult to attract a logging contractor for the removal cut if an economically viable quantity of trees is not maintained.

Application

The shelterwood method is often considered the most flexible and successful of the even-aged reproduction methods for hardwoods. The method can provide for establishment of shade-intolerant species if midstory trees are removed during preparatory or seed cuts and the overstory is removed soon after establishment of advance regeneration. With moderately shade-intolerant to moderately shade-tolerant species, the method can provide for both establishment and early development of seedlings provided that midstory species are removed no later than the seed cut. Finally, the method is very capable for the establishment and growth of shade tolerant species with no work needed for removal of midstory stems.

For oaks, several other considerations are warranted. In general, the preparatory cut does not result in establishment of new oak seedlings (Clatterbuck and Meadows 1993). Advance oak regeneration is typically established over a period of several years, usually after several heavy mast years. During years of lower acorn production, wildlife often consumes a large proportion of the mast crop. Also, if periodic thinnings have been conducted, the preparatory cut may not be necessary. Adequate oak regeneration may already be present although early thinning often promotes development of shade-tolerant species.

Care is needed when conducting shelterwood operations. Harvesting too many trees may result in establishment of shade-intolerant species at the expense of more moderately shade-tolerant species like the oaks. Harvesting too few trees can result in establishment of shade-tolerant species which may outcompete species like oak and ash. When implementing the shelterwood reproduction method to develop advance oak regeneration, it is important remove smaller trees first so that larger, more vigorous overstory stems are retained as seed sources. Removal of residual midstory stems may be warranted if the light levels necessary for continued seedling development are not present. Once advance regeneration has reached an acceptable size, then residual trees are removed.

Variations

The shelterwood method can provide a wide array of variations due to the dual objectives of providing seed and shelter for developing seedlings (Ashton and Kelty 2018). As commonly practiced, the uniform shelterwood as described previously provides that residual trees are distributed evenly across the stand. Basic variations to this uniform pattern are listed below.

Strip Shelterwood Method

The strip shelterwood method involves alternating strips of areas harvested as a uniform shelterwood with unharvested strips or strips utilizing a different reproduction method. Utility of this method for hardwoods is relatively unknown.

Irregular Shelterwood Method

The irregular shelterwood method involves lengthening the regeneration period so that essentially two age classes are managed for extended periods of time (Ashton and Kelty 2018). The term "irregular" is taken from the variation in tree heights within the stand. The irregular shelterwood method is not an uneven-aged (by definition, three or more age classes) method, but it does have two age classes that may complicate silvicultural management of the stand.

Coppice Method

Overview

The coppice reproduction method involves regeneration of stands by vegetative processes, such as root and stump sprouting (Figure 8). In practice, the harvesting operation involved resembles a clear-cut, but regeneration is by sprouting instead of from seed. From an ecological perspective, coppicing is similar to a major disturbance like a windstorm where many trees are downed in a stand. Intact root systems resprout, and in several species, limbs in contact with the ground can even take root. Unlike other even-aged reproduction methods, the coppice reproduction method usually involves removing the entire tree, including branches. Since most objectives involving coppicing are intended to produce fuelwood or biomass, less coarse woody debris is left onsite and can result in nutrient depletion.

Advantages of the coppice method

- It can maintain parent tree genetics onsite.
- Established root systems result in rapid growth.
- Rapid early growth can result in earlier mast production.
- The method produces a lot of browse and low cover that some wildlife species require.

Disadvantages of the coppice method

- Resulting trees are from sprout origin and are inferior in quality to boles developed from seed or advance reproduction.
- Decay of stumps around stump sprouts often leads to decay in the sprouted tree with a resulting decrease in quality and/or stem failure in some boles.

Application

The coppice reproduction method is typically applied in one of two scenarios. The first is in combination with the clear-cutting reproduction method, and the second involves production of hardwood biomass in plantation settings. Coppicing is relatively common, although its usage is rarely recognized. When bottomland hardwood stands are harvested, subsequent regeneration is from seed, advance reproduction, and sprouts. As mentioned in the clear-cut reproduction method section, regeneration from sprouting results from the coppice reproduction method rather than a release of advance regeneration or germination of seed after clear-cut harvesting occurs.

The method is also used in short-rotation woody biomass plantations. Rapidly growing species (eastern cottonwood, American sycamore, black willow, and sweetgum) are planted and then grown for 5 to 10 years with little intermediate treatment. At the end of the rotation, the plantation is harvested for pulpwood or fuel. Instead of replanting the site, stumps from the previous stand are allowed to sprout, establishing a stand for the next rotation. Some thinning of stems within a sprout clump may be necessary to focus growth on one or two stems. This cycle may be repeated several times, but eventually root systems become too large to be supported by the resulting small

Figure 8. A 1-year-old stand of coppice red maple and sweetgum.

stems after harvesting. Once this point is reached, the site is prepared for planting with new seedlings and the cycle of harvesting/sprouting is restarted. For more information on short-rotation hardwood biomass plantations, please consult Mississippi State University Extension Publication 3019, *Understanding Short Rotation Woody Crops*.

Two-Aged Method

Overview

The two-aged reproduction method (also known as the deferment reproduction method and the leave-tree method) is uncommon in the United States but has been used for centuries in Europe and Asia. Essentially, creation of a two-aged stand is similar to that of one created using the seed-tree or shelterwood methods. However, residual seed trees are not removed either until new regeneration has developed into mature trees or they may be left indefinitely (Figure 9). Regeneration is from seedlings established after harvest which develop in openings created by partial harvesting of the parent stand.

Advantages of the two-aged method

- An overstory is present at all stages of stand development.
- It offers an alternative to complete removal of all trees in aesthetically sensitive areas.
- The method provides some continuous overstory canopy for use by various wildlife species.
- Stands can provide mast throughout all stages of development.
- Residual trees, if of good vigor, will increase in diameter and volume.

Figure 9. Two-aged stand initially created using the shelterwood reproduction method. The original plan included removal of residual seed trees, but secondary aesthetics considerations dictated maintenance of remaining overstory trees for aesthetic purposes.

Disadvantages of the deferment method

- Regeneration may not develop well under overstory canopy (depends on the number of residuals).
- Residual trees are susceptible to damage from lightning strikes, windthrow, and ice.
- Seed dispersal for heavy-seeded species, such as oaks and hickories, is limited.
- The potential for log grade reduction in residual trees through production of epicormic branches is high.
- Overall stand marketability and logging productivity are decreased if the best trees are usually left as seed trees.

Application

When using the two-aged reproduction method, overstory trees are harvested, leaving whatever residual basal area is deemed appropriate, similar to establishing a shelterwood. However, unlike in shelterwood cutting, residual trees will be left after establishment of reproduction. These residual trees may be removed during thinning operations once reproduction has reached merchantable size. The cycle can be repeated with the next rotation maintaining an overstory throughout all stages of stand development. This method offers extra potential benefits by not only retaining seed trees for the next rotation but also by selecting some trees for the benefit of wildlife habitat or aesthetic value. Selected trees can be expected to live at least 50 to 80 years after seed cutting (depends on species and stand type, less for bottomland hardwood species).

Here are several characteristics to consider when selecting trees to leave when implementing the two-aged reproduction method:

- Single, dominant stem with no major forks;
- Dominant or codominant crown position;
- No more than 10-degree lean from vertical;
- No more than 15 percent sweep, crook, or decay;
- No dead or dying major branches in the upper crown;
- No signs of developing epicormic branches on the butt log; and
- Not of a species prone to dieback or decline after heavy cutting.

Single-Tree Selection Method

Overview

The single-tree selection reproduction method is intended to create or maintain an uneven-aged stand (three or more age classes) into perpetuity. Individual trees are periodically removed from a stand in several diameter classes to maintain a predetermined uneven-aged diameter distribution. Trees removed from the overstory create small canopy gaps, typically 0.1 to 0.12 acres each on average, that allow for establishment and development of regeneration. Shade-tolerant species are most likely to be successfully regenerated using this method unless additional work is performed to open canopy gaps as adjacent tree crowns widen and fill the gap (Ashton and Kelty 2018). Consequently, it may be difficult to regenerate shade-intolerant and moderately shade-intolerant species using the method. The single-tree selection reproduction method promotes succession by simulating the gapped stand structure associated with old-growth stands. Differences include the absence of felled tree boles, pit/mound topography, and snags associated with death of old trees.

As previously mentioned, single-tree selection favors development of shade-tolerant species (sugarberry, boxelder, hickories, elms, and maples). The small gap size does not allow sufficient sunlight to reach the forest floor for successful regeneration of shade-intolerant species (eastern cottonwood, black willow, American sycamore, sweetgum, and yellow-poplar). There are proponents of the method that support its use to regenerate moderately shade-intolerant species like oak. However, the method has not been proven in management with an emphasis on profitability. Unless a heavy removal regime of repeated stand reentries is established (5 to 10 years and 50 percent or more of the overstory and midstory), it is very unlikely that these species will be successfully regenerated using single-tree selection. Questions concerning subsequent development of these species as the stand develops remain unanswered. Gaps created by the single-tree selection method alone typically do not allow enough space for development and recruitment of these species into the overstory (Figure 10). Such gaps often close before developing regeneration can reach the overstory, hence the need for repeated reentries to further release growing reproduction.

Advantages of the single-tree method

- It can be used to regenerate shade-tolerant species.
- Maintaining continuous forest canopy cover is aesthetically pleasing.
- Stands maximize vertical and horizontal structure for wildlife habitat.

Disadvantages of the single-tree selection method

- It requires frequent stand entry to maintain proper diameter distributions.
- Frequent entry will result in greater damage to residual trees.
- The method does not promote regeneration and development of shade-intolerant or moderately shade-tolerant species.

Figure 10. A canopy gap created by removing a single overstory tree in a bottomland hardwood forest. Little additional sunlight reaches the forest floor through gaps created using single-tree selection. (Photo courtesy of Trent Danley, officer, Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries)

- Considerable economic loss of timber revenue can result when compared to even-aged methods.
- It can be difficult to implement due to lack of experience, research results, and practicality in many stands.

Application

Most bottomland hardwood researchers conclude that the single-tree selection reproduction method is not applicable to hardwood stands, especially for species like oak (Hodges 1987, Clatterbuck and Meadows 1993, Meadows and Stanturf 1997). Many of the species valued in hardwood management are shade-intolerant and are not promoted by the single-tree selection method.

Group Selection Method

Overview

The group selection reproduction method involves removal of trees in small groups (Figure 11). The size of the group opening is subject to debate but generally ranges from 0.5 to 2 acres. A circular opening with a diameter twice the height of the surrounding stand has been considered the maximum size for a group selection opening (Meadows and Stanturf 1997), but larger openings are sometimes considered appropriate. Although regeneration of many bottomland hardwood species can occur in openings of smaller sizes, openings of 1 acre or larger are generally considered necessary for recruitment of shade-intolerant species, which includes most bottomland oaks, into the overstory (Meadows and Stanturf 1997).

Figure 11. Small group selection cut in the Mississippi Delta testing viability of the method in regenerating oaks. (Photo courtesy of Trent Danley, officer, Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries)

Advantages of the group selection method

- Opening sizes are large enough to regenerate most shade-intolerant species.
- A forest canopy covers most of the stand, which is more aesthetically pleasing to many.
- It provides high structural diversity for wildlife habitat.
- The method has proven more successful with regeneration of shade-intolerant and moderately shade-intolerant species than the single-tree selection method.

Disadvantages of the group selection method

- It involves repeated stand entry to maintain uneven-aged stand structure.
- Group selection provides lower revenue compared to even-aged methods.
- The effect of adjacent canopy on development of regeneration is unknown.

Application

As usually practiced, openings of 1 to 2 acres are made in the stand. Areas with adequate advance regeneration of desired species are selected for creating an opening. Areas without sufficient regeneration and areas between group openings are thinned to promote growth of residual trees and start the regeneration process. Entries are usually performed on a 7- to 20-year cutting cycle. Each entry or reentry is used to create new openings, thin between openings, and release or thin trees in old openings as needed. Theoretically, this cycle can be perpetual, but several limitations exist when using this method:

- Initiating the method is complicated because trees established in uneven-aged stands typically are not well distributed in all areas of the stand.
- The edge-to-center ratio of openings is very high, and adjacent trees have a disproportionate effect on the group of regeneration.
- Due to group shape and size, adjacent trees often quickly close the opening as crowns spread.
- The size and arrangement of groups within a forest make them difficult to map, locate, and manage.
- Standard inventory techniques do not provide the information needed for management using group selections.
- Commercial harvesting is complicated.
- Scattered distribution of groups makes it difficult to construct and maintain an access system.

Finally, converting an even-aged stand to uneven-aged status using group selection as the reproduction method is difficult. Assuming an 80-year-old, 100-acre stand, and making ten, 2-acre group selection openings every 15 years, the last group openings will have 140-year-old trees at harvest. These trees will very likely have higher incidences of mortality due to insects, diseases, and abiotic factors such as wind. In addition, the longevity of some short-lived species brings questions of viability with the group selection reproduction method and its longer process of implementation. This problem can be somewhat alleviated by establishing regeneration for these species when thinning between groups.

LITERATURE CITED

Ashton, M. S., and M. J. Kelty. 2018. The practice of silviculture: applied forest ecology. 10th ed. John Wiley & Sons Ltd., New Jersey, 776 p.

Allen, J. A., B. D. Keeland, J. A. Stanturf, A. F. Clewell, and H. E. Kennedy, Jr. 2001. A guide to bottomland hardwood restoration. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0011, U.S. Department of Agriculture, Forest Service, Southern Research Station, General Technical Report SRS-40, 132 p.

Clark, F. B., and S. G. Boyce. 1964. Yellow-poplar seed remains viable in the forest litter. Journal of Forestry 62: 564-567.

Clatterbuck, W. K., and J. S. Meadows. 1993. Regenerating oaks in the bottomlands. Pgs. 184-195 in D. L. Loftis and C. E. McGee (eds.), Oak Regeneration: Serious Problems, Practical Recommendations. USDA Forest Service General Technical Report SE-84, 319 p.

Hodges, J. D. 1987. Cutting mixed bottomland hardwoods for good growth and regeneration. Pgs. 53-60 in Proceedings of the 15th Annual Hardwood Symposium of the Hardwood Research Council, Memphis, Tennessee.

Kellison, R. C., D. J. Frederick, and W. E. Gardner. 1981. A guide for regenerating and managing natural stands of southern hardwoods. North Carolina Agricultural Research Service, Raleigh, North Carolina, 24 p.

Kellison, R. C., and M. J. Young. 1997. The bottomland hardwood forest of the southern United States. Forest Ecology and Management 90: 101-115.

Meadows, J. S., and J. A. Stanturf. 1997. Silvicultural systems for southern bottomland hardwood forests. Forest Ecology and Management 90: 127-140.

Self, B. 2021. Understanding short rotation woody crops. MSU Extension Publication 3019. 4 p.

Self, B. 2020. Bottomland Hardwoods Natural Regeneration Using the Shelterwood System. MSU Extension Publication 3461. 8 p.

Self, B. 2020. Hardwoods: What Is High-Grading? MSU Extension Publication 3451. 2 p.

Self, B. 2019. Tree Injection for Timber Stand Improvement. MSU Extension Publication 2942. 8 p.

Zaebst, T. W., W. M. Aust, S. H. Schoenholtz, and C. Fristoe. 1995. Recovery status of a tupelo-cypress wetland seven years after disturbance: silvicultural implications. Pgs. 229-235 in M. B. Edwards (ed.), Proceedings of the Eight Biennial Southern Silvicultural Research Conference, USDA Forest Service General Technical Report SRS-1, 633p.

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