Shelterwood Establishment Harvest for Upland Oaks

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Practice Objective and Description

The shelterwood establishment harvest (establishment cut) is one step in the shelterwood regeneration system (see Appendix 1) designed to preferentially regenerate intermediate shade tolerant species like oaks. The system is typically composed of a preparatory treatment used to establish vigorous oak advance reproduction (seedling and saplings). Once the oak regenerative capacity is in place, the establishment cut is implemented, removing a portion of the overstory to provide a light environment that preferentially favors oak. A final removal harvest is completed once oak is firmly established as a dominant or co-dominant in the regenerating age class. This last step removes most of or all the remaining merchantable overstory, leaving the regenerating age class with full, or near full, sunlight to optimize its growth.

Specifically, the establishment cut removes approximately 50% of the overstory, generally leaving a total stand basal area in upland oaks stands of between 45 to 65 ft^2 per acre. The reduction in basal area produces an intermediate amount of light (20% to 50% full sunlight) at the forest floor (13) (18) (22) (37). Oaks are intermediate in shade tolerance and will respond well to this treatment, while shade intolerant competitors such as yellow-poplar will not (4) (11) (13) (18) (20) (22) (33) (37) (Figure 1). To consider the implementation of an establishment cut, competitive advance oak reproduction and/or stump sprouting capacity must be present. If it is not, the establishment cut is not warranted and a preparatory treatment and associated practices used to establish adequate oak regeneration should be considered (ex. mid-story removal, soil scarification, under-planting).

Figure 1. Establishment cut showing intermediate light levels and development of regenerating age class. Photo credit: Eli Sagor, University of Minnesota, Bugwood.org.

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When to Apply

There are several attributes that are required to justify this practice. While the establishment cut is a single event, ultimately it is one part of the shelterwood regeneration system (see Appendix 1) and cannot be planned without provisions including a future removal of residual stems retained by the establishment cut. This will maximize the long-term height growth of the regenerating age class (including the oak reproduction cohort). To successfully justify the use of this practice the following attributes should be present:

- Presence of adequate oak regenerative capacity, as indicated by the presence of adequate advance reproduction and/or sprouting capacity from sapling or pole-sized oaks, having the potential to maintain height growth with competing species in the regenerating age class (see Reproduction in Section 9).
- There are shade intolerant competitors in the regenerating age class that can interfere with the establishment and recruitment of oak into dominant or co-dominant canopy positions. The "sheltering" reduction of light levels is required to hinder the development of these competitors that can originate from established (advance) reproduction, trees with high sprouting potential, or new seedlings generated from seed present or deposited directly after the establishment cut.
- The stand should have the potential to support a commercial harvest while retaining approximately 50% of the total stand basal area, with valuable or potentially valuable overstory trees capable of supporting a commercial harvest in the next 10 to 20 years (unless funds and/or resources are available for the non-commercial removal of the residual overstory).
- Ability to remove non-commercial stems where necessary to reach the retention target of 45 to 65 ft^2 per acre. If removal of sufficient basal area cannot be accomplished with a commercial harvest, other practices such as site preparation or a liberation treatment must be used and provisions for completing these practices are required.

Application for Social, Aesthetic, or Wildlife Concerns or Objectives

The use of the establishment cut has the potential to meet social or ecosystem services concerns. For example, retaining approximately 50% of the overstory creates residual stand structure and composition that is generally more visually acceptable than clearcutting. Partial retention of overstory trees also provides the opportunity to retain attributes advantageous to wildlife (ex. acorns for hard mast, nesting habitat) with larger-diameter, high acorn producing trees being retained (2). Ultimately, removal of the majority of the overstory should be planned regardless of objective to ensure recruitment and retention of oaks.

Associated Practices

The establishment cut requires removal of approximately 5% of the overstory stand basal area. In nearly all cases, it is implemented with a commercial harvest. To meet total stand residual basal area targets, non-commercial overstory trees may need to be removed. Further, mid-story and understory trees that can interfere with the development of the new regenerating age class may need to be removed if a preparatory treatment has not already done so. However, these removals become difficult if pulpwood or other markets for small diameter and/or low-quality trees are unavailable. If the commercial harvest cannot remove adequate basal area and a large percentage of the trees' mid- and understory competition, a site preparation treatment, typically using herbicides, directly before or after the establishment cut is required. See Site Preparation for Regeneration of Upland Oaks FOR-164 (41). Also, in some situations, prescribed fire can be used after the establishment cut to topkill small woody stems. However, it will take repeated burning (often three or more) to start to significantly exhaust species that can interfere with oak advance regeneration development. The periodicity and seasonal timing of the burns are critical to make this treatment work effectively, especially on sites with significant oak competitors. In the latter case, burning has the potential to reduce the overall basal area of the mid- and understory and adjust species composition to the advantage of the oaks. On lower quality sites, often with less competitive pressure, prescribed burning can be used to reset advance regeneration, and the oaks can resprout vigorously and often be expected to prevail against the competitors they do have. Regardless of site quality, prescribed burning is a complex prescription to implement in hardwood stands, and the results can be highly variable compared to a herbicide treatment to control competing species. For more information on using fire in this context, see Prescribed Fire for Upland Oaks FOR-165 (38). Regardless of the associated treatment used to reduce competition and improve oak advance reproduction, it is important to ensure that the establishment cut maintains the proper basal area providing the appropriate light levels to foster oak development in the regenerating age class (Figure 2). If the site preparation treatment cannot be administered in this time frame, a liberation treatment can be used several years later. Also, as previously discussed, the establishment cut is only one part of the shelterwood regeneration system.

Figure 2. Preparatory treatment (mid-story removal) to encourage regeneration development prior to the establishment cut. Painted overtopped and intermediate crown class trees subjected to chemical treatment using hack and squirt.

See Appendix 1 for an explanation of other practices associated with the system including practices to establish oak advance regeneration, a preparatory treatment, and removal of a significant amount of the residual overstory after the establishment cut.

Common Examples of Where the Practice is Applied
Typically, this practice is implemented in stands that are fully stocked, sawtimber sized, economically mature, and oak dominated. These stands must also possess oak regeneration-recruitment potential. Oak dominated stands occur across a wide range of site qualities, and site quality can play an important part in determining where this practice is required; generally it is most effective on sites with upland oak site index between 65-75 feet (see Site Considerations Section 10).

Examples of Conditions or Situations that Limit Effectiveness
There are several economic and biologic conditions that can significantly reduce the establishment cut's effectiveness or make the practice difficult to implement, regardless of site quality, including:

- Inability to remove un-merchantable trees to reach target basal area retention due to a host of social, operational, or economic factors. The lack of markets for marginally valued sawtimber, pulpwood, and other low-valued products can create or exacerbate fiscal challenges to removing enough overstory and interfering midstory, intermediate, and overtopped crown class trees to be effective in initiating regeneration.
- Lack of oak regeneration potential, as indicated by the absence of overstory oak seed sources, limited stump sprouting potential due to low density of stems with high sprouting potential, or inadequate numbers of existing oak reproduction.
- Changed disturbance regimes which have greatly shifted understory composition to shade-tolerant species, while maintaining seed sources for intolerant trees in the overstory.

While these conditions are not insurmountable, they certainly make the effective implementation of an establishment cut fiscally and biologically challenging and often require the use of additional intense practices and treatments to meet oak regeneration goals.

Post-implementation Conditions
After completion of the establishment cut, the upland oak stand should contain approximately 45 to 65 ft^2 of basal area in dominant, codominant, or strong intermediate crown class trees that retain enough market value or potential market value to facilitate their harvest in 10 to 20 years (12). Residual trees should be of high vigor, with appropriate crown-to-bole ratios (25). Trees with these characteristics are most likely to withstand open conditions. Further, for landowners with a timber objective, these trees are less likely to exhibit epicormic branching that has the potential to degrade future timber values. This residual stand basal area target can be accomplished with the establishment cut and/or in combination with site preparation treatments (Figure 3).

Figure 3. Recently implemented shelterwood establishment cut showing intermediate light levels and initiation of new age class.

Practice Use Within a Silvicultural Framework
This is a regeneration practice that is used near the end of an economic rotation to stimulate establishment of a new age class. The establishment cut results in a two-aged stand, residual overstory overtopping a regenerating age class. Ultimately, the overstory should be removed to provide an even-aged stand. As indicated previously, this practice is a part of the shelterwood regeneration system (see Appendix 1) and is nested within a suite of other practices needed to ensure oak success.

Data and Observations
The establishment cut is a relatively complex treatment to prescribe. This is because it requires both attention to regeneration along with specific requirements for overstory retention. The latter requires attention to biologic and economic overstory assessment. All these factors indicate that a significant amount of information needs to be collected to determine if the practice should be implemented and how it should be administered. Information is required to gauge reproduction and assess the overstory. The following provides an explanation of the types of information required and recommendations for data collection methodologies.

<u>Reproduction</u>
To justify this practice the stand must have the potential to regenerate upland oaks and requires data collection (or observations) to determine oak regenerative potential, including estimates of oak advance reproduction and stump

sprouting capacity. Unfortunately, providing quantitative estimates to accurately predict regenerative potential can be difficult. Ultimately, the objective of any oak regeneration treatment is to ensure that there are approximately 120 dominant or codominant oaks at stem exclusion (typically 10- to 20-years-old depending on site productivity) to achieve 50% oak stocking at stand maturity (3) (34) (42). These codominant oaks will be a product of:

1. the number and vigor of oak advance reproduction (seedlings) and larger oaks that can stump sprout (after they are purposely cut or damaged during harvest)
2. the strength of competing species.

Reproduction Targets

Generally, to achieve 120 codominant oaks in a 10- to 20-year-old stand requires 150 to 400 stems per acre (33) of advance oak reproduction at least 3 to 4 feet tall and/or 20 to 30 sapling (2- to 6-inch dbh) or pole-sized (6- to10-inch dbh) trees per acre that can be cut and left to stump sprout. The required number of both advance reproduction and stump sprout trees is largely related to site productivity as an indicator of competition. On lower quality sites, successful oak regeneration could be obtained if you had a combination of 10 stump sprouters and 50 to 100 advance reproductive stems 3 to 4 feet tall. Likewise, a combination of 15 stump sprouters and 200 to 400 advance reproduction stems would be prudent on higher quality sites. Also, it is important to gauge the sprouting capacity of saplings and pole-sized trees. Sprouting capacity is species- and age-dependent (9) (23) (44). Red oaks should generally be less than 30- to 40-years-old, while white oak can maintain sprouting capacity to 60 to 80 years (24). Optimally, trees selected for stump sprouting should be between 4- to 6-inches in dbh, as research has shown that this size produced the largest number of dominant and co-dominant trees in 25-year-old stands (43) (44). On higher productivity sites, select larger trees within this size class.

Overstory

While this practice requires an initial commercial harvest to a target residual basal area, the shelterwood regeneration system also requires a future harvest to remove the remaining overstory that will release the oak reproduction cohort. The second removal can be a complete removal of all merchantable stems, or a partial removal used to retain trees with attributes that meet ownership objectives such as aesthetics, acorn production for wildlife, or future high value timber. The second entry typically occurs 10 to 20 years after the initial removal and is dependent on individual stand and site characteristics. Because most stands suitable for a shelterwood treatment are mature and fully stocked or overstocked, the establishment cut should be economical while leaving enough desired residual stems for a second harvest in 10 to 20 years. The key is to ensure residual trees will meet future merchantability needs. Data must assess the stand's current and residual merchantability. Plot-level data or a total inventory, if it is customary to do so for a timber sale, should be collected to provide information on both current and future volume and value. Tally data of dominant, co-dominant and strong intermediate crown class trees should include species, diameter, volume, and current and future merchantability/value. While estimating current merchantability involves the use of local merchantability standards, future merchantability requires a projected merchantability/value or surrogates for them. The latter can be accomplished by using either the current merchantability, assuming that at a minimum it will be present 10 to 20 years in the future or by projecting future merchantability.

Site Productivity

As indicated previously, it is important to estimate site productivity to make decisions on what constitutes appropriate numbers of advance reproduction and stump sprouting trees. It is also important to recognize that there is a maximum site index that oak, particularly white oak, can be successfully managed. On highly productive sites (upland oak site index of 75–80 ft. or greater), it is very difficult for white oak to maintain sustained height growth to keep pace with shade intolerant species that may seed in after the establishment cut (ex. yellow-poplar). Northern red oak can be expected to compete better on these sites, as it has a greater height growth capacity than white oak. However, there may be an upper limit for this species as well.

Data Collection

The type and detail of data needed is situation dependent. For example, if reliable models or programs that can estimate regeneration outcomes are available, then it is recommended to use these and collect data as required for their use. This might entail collecting data for both oak and non-oak species. If these resources do not exist, use the targets for advance reproduction and stump sprouting trees provided above. Data is typically collected using small, fixed-area plots, or sometimes fixed-width transects, for advance reproduction and larger fixed-area plots or point sampling to determine data for sapling, pole, and sawtimber sized trees.

- Oak Advance Reproduction – Data is typically collected from relatively small (ex. 1/100 acre) fixed-area plots or transects. Tally the number of oak advance reproduction (seedlings) stems by 1- or 2-ft height classes for stems up to 4.5 feet tall and the number of stems between 4.5 feet tall and 1.5 inches in dbh.
- Oak Stump Sprouting – Collect data on the number of oak stems having stump sprouting potential between 1.5 inches dbh and 10 inches dbh. This can be done using the fixed-area plots used for advance reproduction or variable-area plots (prism plot sampling using a 5 basal area factor prism) can be used to determine the number per acre of sapling and pole-sized oaks. A measure of the age of these stems is required to ensure they have the potential to

sprout (30¬to 40-year-old maximum for red oaks and a maximum of 60- to 80-year-old for white oak).

- Competing Species – Competing vegetation can pose a barrier to successful oak regeneration by limiting available light and growing space. An establishment cut will affect the entire reproduction cohort, including non-desirable species. If there are an abundance of shade-tolerant stems in the understory and midstory, additional treatments may be needed to ensure oak development, and recruitment is not hindered by this competition. If a preparatory treatment is used, such as a herbicide mid-story removal, many competing stems will be eliminated and their sprouting potential negated. Assessment of interfering vegetation using a fixed- or variable-area plot to determine the density and basal area of potential competing stems, including residual trees, will guide a treatment decision. This assessment will provide information needed for practices related to site preparation associated with the harvest, such as treating cut stumps, or individual tree injection or hack-and-squirt.
- Site Productivity – Site quality plays a significant role in driving factors critical to the use and success of a shelterwood establishment cut and has been repeatedly referenced. Site index estimates should be established, either using existing stand information or available site index associated with landscape position. Site index can also be directly obtained from age and total height measurements of existing free-to-grow dominants or co-dominants. Select a minimum of three trees per stand, preferably oaks. Or use species where comparative data exists allowing oak site index to be estimated from non-oak species. Typically, Schnur's upland oak site index curves (34) are used to determine oak site index as discussed above.

Planning and Marking

As indicated in the previous section the practice is complex. The complexity of implementing a partial removal of the overstory with specific biological, spatial, and economic attributes at the proper time to enhance the development of oak regeneration requires sophistication. Practice success requires the development of robust marking guidelines, careful implementation, and proper timing.

<u>Implementation Attributes</u>

- Removals and Retention – Given the importance of providing a suitable amount of retention for creating appropriate understory light conditions, accurate implementation is critical, and removals should:
    - result in 45 ft^2 to 65 ft^2 of total residual basal area
    - result in relatively even distribution of the residual basal area across the stand
    - ensure that the majority of the retention is in dominant, co-dominant or strong intermediate trees (the latter the least desirable)
    - retain enough economic value in the retention to support a harvest in 10 to 20 years.

- Residual Damage – As retention must be maintained for 10 to 20 years after the treatment and the economic value of the retention is important, it is critical that logging damage is minimized. This involves considerations in the marking as well as the timing of the treatment. On steep slopes or other situations where skidding (or forwarding) is constrained to constructed skid trails, most of the damage occurs during felling. On gentle terrain, where constructed trails are not required, skidding resulting in basal damage is the primary concern. Research has shown that in most instances residual tree damage can be held to a maximum of 10% of the residual overstory trees (15). This includes damage such as knockdown, main stem or major branch breakage, and bark removal from felling or skidding that results in greater than 100 in^2 exposure of wood on the butt log (28). In manual harvest operations (chainsaw felling), directional felling techniques should be required and monitored by observing felling and/or by stump inspections after felling. Attention to skid trail layout, length of stems skidded, use of bumper trees, and other log quality control methods can reduce skidding damage by conventional ground skidding equipment.
- Reproduction – The establishment cut should remove the required overstory and interfering lower canopy trees to enhance understory growing conditions for oak reproduction. The cutting of interfering trees can be accomplished as a part of the harvest operation, which often requires a strong market for smaller diameter material (hardwood pulp, pallet, and biomass). Where these markets are limited, the removal could be completed by the logger, but may require a reduction in timber revenue to offset the removals of non-merchantable stems. These stems should be marked or a description of trees to be removed should be included in harvest guidelines. If the removal is accomplished as a part of the harvest, typically these stems will be cut and left to stump and/or root sprout. If the oak reproduction is large or there is a significant oak stump sprouting potential, the sprouting of the interfering stems may not be problematic for oak development, and shade created by sprouts may deter new seedling establishment of light-seeded and shade-intolerant species such as yellow-poplar. However, if this is not the case, there would be value in chemically treating interfering stems to reduce or eliminate sprouting, thus reducing competition for the oak reproduction (9). While some logging operations may have this capacity, it often requires a separate site preparation treatment using herbicides as cut-stump, injection, hack-and-squirt, or basal bark applications. These treatments can occur before or directly after the harvest. Regardless, such treatments are often essential to creating understory conditions conducive to the establishment of competitive oak reproduction, the necessity increasing with site quality and where competitive species are in abundance. Attention should also be paid to ground skidding to avoid unnecessary damage to physical site conditions such as soil and litter and to the advance reproduction (21) (39). While large advance reproduction (greater than 4-feet in height) has high sprouting potential, soil compaction can reduce growth (30).

Marking
As the practice is commonly implemented with a commercial harvest, it would be common to mark removals. However, given the importance of the amount, distribution, and quality attributes of the residual overstory, it is recommended to mark the trees to be retained indicating that all other trees are to be removed. Marking residual trees highlights their importance, facilitates transfer of this importance to the logger, and makes monitoring easier. It also may be less expensive. If residual trees are to be painted, ensure that the marking is highly visible to the operator (the latter may require paint on more than one side of the stem), and on the lower bole just above ground level for verification purposes. The importance of the residual stand also requires that damage to retained overstory is minimized. Care must be taken to ensure removals can be felled without extensive damage to residuals. As an example, marking should avoid retaining small diameter residuals directly downslope from large diameter removals. Marking should consider residual stand structure and composition to create the targeted residual basal area that maintains appropriate potential economic value.

Timing and Seasonality
Concern over the detrimental impact that heavy harvest machinery has on soil physical properties and site productivity and wounding of residual trees dictates that most harvesting operations be done during dry weather conditions of summer and early fall. This is congruent with minimizing residual tree damage, as tree bark is more susceptible to injury during late winter and early spring. While harvesting during the earlier part of the growing season has been shown to reduce sprouting, which can be advantageous in reducing sprouting from interfering trees, research indicates that there is limited impact on many interfering species found in upland hardwood stands (14).

Site Considerations
The establishment cut can be effectively implemented across a range of sites and stand conditions that include soil moisture, potential machine disturbance, and slope influences on felling and residual damage. Medium productive sites (upland oak site index 65-75) where oaks dominate the overstory, are lacking from the midstory and are sparse in the understory, are the best candidates for a shelterwood system. Site quality can influence the justification to the use the practice or impact its effectiveness.

Low Productivity Sites (upland oak site index of < 60-65)
Productivity on these sites is often restricted due to limited soil moisture resulting in conditions suitable to oak reproduction success mainly due to reduced competition (1) (5). Lower quality sites commonly have desired oak regeneration potential (stump sprouting and large and numerous advance reproduction) that can match or exceed the height growth of competitors. If this is the case, an establishment cut would generally not be warranted as the oak regenerative potential is high without the need for sheltering and suppression of interfering vegetation.

High Productivity Sites (upland oak site index > 75-80)
These sites often contain shade-intolerant species that reproduce by seed, are fast growing, and dominate regenerating oaks when the stand is disturbed. Unfortunately, these sites often contain limited oak advance reproduction and limited oak sprouting potential. The combination of these attributes indicates that there are limited opportunities for the use of the establishment cuts without significant preparatory work as outlined in Section IV. Despite robust oak reproduction, the shade-intolerant competitors will pose a risk, even with their height growth restricted by the partial shade imposed by this practice. Because of this, evaluation of the oak in the regenerating age class is warranted and release treatments may be required to sustain them on these high-quality sites. In summary, care must be taken in using this practice on high productivity sites and tending to further release recruited oak should be considered.

Barriers to Success
Barriers to use of the establishment cuts include:

a. lack of wood markets to support appropriate removals,
b. limited oak regeneration potential,
c. occurrence of, or the potential occurrence of, significant competitors,
d. planning, implementation, timing, costs, and dedication to success.

Because the establishment cut is part of the shelterwood regeneration system, there are barriers to other parts of the system that should be considered. These include a lack of markets that might preclude the future removal of the residual overstory; the inability of being able to conduct site preparation practices to remove interfering vegetation over time; landowner changes resulting in changes of management priorities; and risk factors associated with maintaining partial overstory cover. Another concern, damage to residual trees from harvesting and/or prescribed fire, can be minimized by using proper timing and implementation. Understanding the complexity of the application of the entire shelterwood regeneration system is paramount to the ultimate success of the establishment cut.

Monitoring
Monitoring can be accomplished observationally or with data collection and analysis if warranted. The following provides detailed information on post-implementation monitoring.

e. Assessment of the total residual stand density to determine if the correct basal area has been retained in the appropriate crown classes. Determination of residual basal area by crown class is required to determine if retention hits the 45 to 65 ft2 basal area per acre target in dominant, co-dominant or strong intermediate crown classes. If monitoring indicates that total basal area is above this level, additional treatments may be required to reduce the total basal area. Harvest damage assessment of residual overstory trees is required to determine if the harvest degraded potential timber value of the overstory trees that is necessary to provide economic support for their removal in 10 to 20 years. If the potential economic value of the overstory has been significantly degraded, plans must be made to treat or remove a significant amount of the residual overstory without the aid of a commercial harvest.
f. Harvest damage assessment of residual overstory trees. Continued monitoring of the condition of residual overstory trees is required to determine if the target basal area for retention is being maintained. Damage assessment is also needed to determine if damage would result in a significant loss of future value in the residual overstory. Degradation in either of these conditions might warrant a re-evaluation of maintaining the shelterwood regeneration system.
g. Recruitment of oaks into competitive positions to time final harvest. This requires determining the impact of the practice on advance oak reproduction and/or oak sprouting capacity. Ground equipment including felling machines, skidders, and forwarders can cause oak reproduction damage ranging from eliminating seedlings or saplings or breaking the main stem at the ground-line or above (28). Breakage could result in sprouting, which can be counted on to maintain oak regeneration. Because of this sprouting potential, it is recommended to monitor regeneration after a full growing season. Use the same sampling procedure as described in Section 9. Assess the intact oak reproduction and sprouting and compare it to the pre-treatment data and the reproductive targets in Section 9.
h. Implementation of site preparation practices. If the establishment cut significantly reduced the numbers of oak seedlings or saplings or stump-sprouting oaks, then additional monitoring of their development is certainly warranted, and plans should be made to intervene with a release treatment as needed in the future (typically after stem exclusion) to keep adequate numbers of oaks in a competitive position in the regenerating age class. White oak with its slower growth compared to other oaks may be more susceptible to overtopping and the need for release prior to stem exclusion may be warranted (see Section 15).

Costs

Since this practice is implemented with commercial harvesting, a net income is expected. However, there are several costs that will or can reduce the overall net revenue associated with the implementation of an establishment cut. These are outside administrative costs associated with a standard timber sale and include:

- Marking costs if in excess of what would be used for typical timber sales (see Section 9 Marking).
- Loss of revenue compared to a traditional timber harvest that would remove more merchantable overstory than the establishment cut.
- Costs associated with monitoring of harvest damage associated with protection of residual overstory trees.
- Costs of site preparation treatments to remove competing trees, not removed in the harvest, to reach total stand basal area targets.

White Oak

Specific to white oak, issues arise that are associated with the development of adequate white oak reproduction, the degree of overstory retention, and potentially epicormic branching. The longevity, shade tolerance, and relatively conservative growth strategy of white oak are important considerations for adjusting the practice to favor white oak. Shade Tolerance and Its Impacts on Practices – Oaks are generally classified as intermediate shade-tolerant. However, there is a gradient of shade tolerance among oak species, and white oak is one of the most shade-tolerant upland oaks. As with many species that have some shade tolerance it displays a conservative growth strategy, putting more carbon resources initially in root development, impacting seedling height growth (31). The shade tolerance also results in seedlings, saplings, and pole-sized trees lingering in stands with a low degree of vigor. These characteristics can have implications for management and the use of this practice as indicated below.

<u>Evaluation of Advance Reproduction</u>

The shade tolerance of white oak allows for oak seedlings to persist for a number of years as small seedlings, losing vigor as they age. It is common to find 1- to 2-foot tall white oak seedlings, growing in shaded understories that have tops between 10 and 20 years old (10). Bud scale scars can be used to estimate top age (assuming one flush per year). These are not vigorous seedlings, and while they may have large root systems, the available carbohydrate stores may be limited (10). Seedlings with these characteristics may take many years to respond to release. Larger white oak advance reproduction is needed as site quality increases for white oak to compete in a regenerating age class. While 3 to 4 feet has been traditionally used as the height required for competitive response (32), detailed recommendations have not been well documented for white oak, and will no doubt range depending upon site productivity. However, on-going research clearly indicates that white oak advance reproduction 2 feet tall or less is insufficient on medium and high-quality sites. These studies also indicate that larger 4- or 5-feet tall advance reproduction with well-developed leaf area and apical dominance have the potential to maintain themselves for a period in a regenerating age class. However, even these larger seedlings may easily be overtopped by strong competition, the higher the site quality the higher the probability of this occurring. White oak, because of its slower height growth compared to some co-occurring oak species, is particularly susceptible to this problem. Because of this, evaluation of regenerating stands prior to stem exclusion should be undertaken to determine the competitive status of white oak reproduction, especially on medium and high-quality sites. When competition is significant, treatments to "rescue" these white oaks may be needed for those that are being overtopped prior to stem exclusion.

Evaluation of Stump Sprouting Potentials

In mature upland hardwood stands, due to white oak's shade tolerance, 60 to 80+-year-old pole-sized white oaks, may be present. For white oak, parent tree age and the interaction of age and tree diameter drive sprouting response. Sprouting probability decreases with increasing age and diameter (8). This is important, as white oak losses the ability to sprout at ages beyond 65 years, and by age 80 limited or no sprouting should be expected. No sprouting was found in trees greater than 80 years old (23). Attention must be paid to the age of potential stump sprouters (overtopped and intermediate crown class oaks). Tree age should be collected to determine sprouting potential.

Residual Overstory Density

The higher shade tolerance of white oak reproduction, compared to other oaks, allows use of the high end of the recommended residual basal area, 65 ft2, to preferentially culture white oak reproduction. However, higher light levels will improve the survival and growth of white oak seedlings, and a goal should be to provide light > 40% of full sunlight (4). Thus, our contemporary forest structure and composition may still dictate intense tending efforts to maintain white oak reproduction in competitive positions.

Epicormic Branching

White oak is well known for its propensity to develop epicormic branching that can lead to long-term reductions in stem quality as it relates to lumber and veneer values. Epicormic branches are produced by suppressed buds that are associated with certain bark abnormalities. The epicormic branches develop from the buds due to damage to the crown of the tree, prolonged suppression of the tree, and exposure to sunlight. The suppressed buds represent a pin knot in the underlying wood and the development of epicormic branches increases the size of the underlying wood defect (knot). However, if the trees are harvested shortly after the epicormic branching appears, the knot present in the underlying wood will be contained in the slab wood and will not impact lumber or veneer quality. But if the tree is left standing for a long period of time under conditions that allow the epicormic branch to grow into larger branches, the underlying defect in the wood becomes bigger and occurs deeper into the stem thus potentially degrading wood value. Hence, the issue with epicormic branching and the establishment cut has to do with the interval between the establishment cut and the final harvest that removes the residual overstory. While this issue is not a specific concern with the establishment cut, it is prudent to consider, as it can ultimately impact timber values that can affect the final harvest and value to the landowner. One means of decreasing the impact of epicormic branching is to select residual overstory trees that are less likely to produce them after they are exposed to the increased sunlight filtering through the open canopy produced by the establishment cut. Because the epicormic branches are produced by suppressed buds associated with bark abnormalities, the following table provides guidelines for determining which bark abnormalities are of concern and which are not. Selecting white oak trees with a reduced number of bark abnormalities will result in reducing the long-term impact of the establishment cut on future timber values associated with the final harvest.

Table 1. White Oak Suppressed Bud Number by Defect Indicator and Number of Epicormic Branches Produced Three Years After Release (from 123 trees subjected to crown release).

Defect Indicator	Number of suppressed buds	Number of epicormic branches three years after release
Live branch	10.0	2.5
Epicormic branch cluster	9.1	1.1
Individual epicormic branch	7.7	1.3
Suppressed bud cluster	4.7	1.0
Dead branch stub	3.9	0.7
Epicormic branch distortion	0.8	0.1
Heavy branch distortion	0.1	0.03
Suppressed bud	0.04	0.01
Medium branch distortion	0	0

Light branch distortion	0	0
Bird peck	0	0
Surface rise	0	0
Bump	0	0
Seam	0	0
Wound – old	0	0
Wound – new	0	0
Source: J. Stringer, University of Kentucky, Department of Forestry and Natural Resources.		

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Appendix 1. Shelterwood Regeneration System

The shelterwood system is a series of treatments designed to produce or maintain forests that are composed of intermediate shade-tolerant species, like oaks. The number of treatments involved depends upon the initial condition of the forest, often determined by the productivity of the site they occur on. In many mesic and submesic oak forests, the reproduction cohort is often dominated by a high density of shade-tolerant species (e.g. red maple, sugar maple, American beech), that reduce understory light and increase competition for oak. In mature oak forests, there may be thousands of small (< 1-foot in height) uncompetitive oak seedlings (7). Shelterwood systems in these situations are typically composed of three main treatments: preparatory, establishment, and a final removal harvest. When this system on these sites is used to encourage oaks, it is typically referred to as the oak shelterwood system (40). Preparatory treatments are used to recruit smaller oak seedlings into larger size classes prior to their partial release as part of the development of a robust regenerating age class produced by the second treatment in an establishment cut (13) (19) (26) (27) (36).

Preparatory Treatment

The preparatory treatment is used to establish and recruit adequate numbers of large advance oak reproduction. A chemical mid-story removal (16) is typically used to enhance existing oak advance reproduction (3) (6) (13) (19) (26) (29) (35) (37). The practice is implemented to remove overtopped and intermediate crown class trees providing an increase in filtered light allowing seedlings to survive and grow. Fortunately, many sites with lower productivity will have adequate oak regenerative capacity and a preparatory treatment is not needed. However, on many medium- and high-quality sites, little competitive oak reproduction is present. This is because the existing mesic and submesic oak forests found on these sites have understories dominated by shade-tolerant species (e.g. red maple, sugar maple, American beech) reducing light levels at the forest floor and suppressing oak seedling growth (7). The mid-story removal treatment is applied when seedlings have established. The treatment is typically implemented by using herbicide to deaden non-oak midstory stems (17). This preparatory treatment has two effects. First, it increases diffuse lighting to aid the small oak reproduction allowing it to gain size and vigor before the establishment cut (13) (19) (26) (27) (36). Second, it reduces shade-tolerant species so they are not present when the establishment cut is implemented, thus improving the odds for successful development of oak in the regenerating age class from advance oak reproduction and stump sprouts while limiting significant response of shade intolerant competitors (18).

It is important to recognize that the preparatory treatment requires the presence of advance regeneration. If this oak advance regeneration is not present another treatment can be used to help establish seedlings. Typically, it is advantageous to allow seedlings to naturally establish after bumper acorn crops occur. In some instances, practices can or must be used to increase seedling numbers (ex. soil scarification (17)) that incorporate acorns into mineral soil, improving germination and establishment. Other, more intensive practices, such as under planting oaks can also be considered. The natural acorn deposition and the treatments used to facilitate seedling development are typically used in conjunction with a mid-story removal discussed above.

Establishment Treatment (Cut)

The objective of the establishment cut, detailed in this publication, is to initiate a robust regenerating age class, providing intermediate light levels to assist the seedling and sapling oak cohort to maintain a competitive advantage in the developing age class. The intermediate light level and the robust oak reproduction produced by the preparatory treatment used on mesic and submesic sites is sufficient to maintain itself against competing species, helping to ensure that oak will ultimately replace the initial overstory (13) (18) (22) (37).

Final Removal Treatment (Harvest)

The final removal harvest to complete the system requires the removal of all or a significant portion of the residual overstory. If not all the residual overstory is removed, the system is termed an irregular shelterwood. Regardless, the result should provide close to full sunlight providing for an increase in height growth of the regenerating age class. As is the case with the establishment cut, the final removal is normally completed with a commercial harvest. The final harvest is completed once oaks have established a competitive advantage in the regenerating age class. The increased light from the removal cut allows for optimum growth of the oaks. This is predicated on the fact that adequate numbers of large advance oak reproduction are established, thus providing conditions for the unimpeded growth of this developing oak cohort. The amount of time to develop the adequate number of oak stems in the new age class and the time between the establishment cut and the final removal cut depends on many factors, such as species, site characteristics, and competing vegetation, but is typically 10-15 years.

NRCS Conservation Practices

- Core Conservation Practice: Forest Stand Improvement (Code 666)
- Supporting Conservation Practice: Brush Management (Code 314) and Herbaceous Weed Control (Code 315)

"Caring for Your White Oak Woods" USDA Natural Resources Conservation Service, 2p.

The selection of prescriptions included in the Upland Oak and White Oak Silviculture Practice Series were established through consultation with silviculture researchers and state forestry management personnel across the region. The peer reviewed individual silvicultural prescriptions were authored by research silviculturists with significant experience in oak management. This series was designed to provide silvicultural guidelines that be used by practitioners and managers along with their knowledge and familiarity with local stand conditions, markets, and contractor expertise to make decision enhancing regeneration, recruitment, and growth and development of upland oaks with a special emphasis on white oak. Other publications in the Series and information on white oak sustainability can be obtained at www.ukforestry.org and www.whiteoakinitiative.org.

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