THE FUNDAMENTALS OF RELEASE BURNING IN MIXED OAK FORESTS WITH EMPHASIS ON THE SHELTERWOOD-BURN TECHNIQUE

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Abstract—Release burning is the term used to describe prescribed fire conducted in the mid- to latter stages of the oak (*Quercus* spp.) regeneration process to promote the dominance of oak reproduction. In this context, the fire exploits differences in resource allocation (roots versus stems) between oak seedlings and those of other hardwoods to free the oaks from excessive competition. Fire seasonality and fire intensity strongly influence release burning outcomes with hot fires conducted in late spring being most beneficial for promoting oak dominance. However, release burning must be used wisely as it can produce unintended consequences regarding whitetail deer (*Odocoileus virginianus*) browsing, damage to overstory trees, invasive species, and smoke impacts.

INTRODUCTION

To correctly use prescribed fire in oak (*Quercus* spp.) forests, one must first understand the oak regeneration process and its relationship to fire (Arthur and others 2012, Johnson and others 2009). The oak regeneration process is the procedure by which mature oaks are replaced by their progeny. It consists of three phases (acorn production, establishment of new oak seedlings, and development of those seedlings into competitive-sized individuals) and an event – an adequate, timely release (Johnson and others 2009, Loftis 2004). The oak regeneration process usually spans a decade or more due to the sporadic occurrence of large acorn crops and the emphasis on root development by young oak seedlings. Oaks typically have heavy masting events every 5 to 10 years depending on species and location (Burns and Honkala 1990). Acorn crops are subject to numerous environmental factors that can slow this phase of the regeneration process or delay it entirely until the next mast year (Arthur and others 2012, Johnson and others 2009). For example, diseases, insects, and weather can ruin acorns before they fall from the trees or, once on the ground, acorns can be destroyed by these same factors or consumed by wildlife. Once an oak seedling cohort forms, these seedlings grow slowly for several years as energy is focused on root system development if adequate resources, especially light, are sufficient for oak seedling survival and growth. Like plentiful acorn crops, the root development phase of the regeneration process can be slowed, stalled, or forced to begin again due to numerous environmental factors. Pre-eminent among these are the amount of understory shade, whitetail deer (*Odocoileus virginianus*) browsing, and the amount and composition of competing vegetation (Brose 2011a, 2011b; Miller and others 2014). Eventually, if the oak reproduction becomes large enough to successfully compete on that site, it can be released by overstory harvests. Because of all these factors, the oak regeneration process is excruciatingly slow, typically lasting 10 to 25 years (Carvell and Tryon 1961, Clark and Watt 1971, Sander 1972).

The first steps of using prescribed fire in oak forest management are to decide what type of future oak forest is desired and determine where the prospective stand is in the oak regeneration process. The desired future condition is dictated by the management objectives while the current condition is ascertained by an inventory. The inventory is an absolute necessity for determining whether oak-stand replacement is feasible or worth pursuing. The inventory can be a simple walk-through evaluation by a forester experienced with local conditions, or a more comprehensive, systematic assessment such as those done in conjunction with prescriptive expert systems like SILVAH (Brose and others 2008), or some other type of forest inventory that falls between these two extremes. Regardless of the degree of complexity of the inventory, it must provide basic information on overstory, understory, and regeneration conditions to determine the oak regeneration potential, as well as to identify potential obstacles to forest renewal and sustainability of oak. Only after an inventory reveals where the stand is in the

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oak regeneration process can the correct type of fire be prescribed and coordinated with other silvicultural practices to meet the management objectives.

There are three types of prescribed fire that are appropriate in oak ecosystems. They are: (1) seedbed preparation burning, (2) release burning, and (3) ecological restoration burning. Because other presenters at this symposium covered seedbed preparation burning and ecological restoration, this paper focuses on release burning and provides guidelines on how to conduct this type of prescribed fire and also presents pitfalls that can negate the desired outcome of the prescribed burn.

RELEASE BURNING

This type of prescribed fire occurs in oak stands nearing the end of the oak regeneration process, where an abundance of large oak advance reproduction is present. There are two types of stands suitable for release burning: those undergoing a shelterwood sequence to promote further development of oak advance reproduction and those that have just been regenerated via a final harvest (fig. 1). Both have the same two characteristics: oak reproduction that is still viable despite being overtopped by taller competing regeneration of mesophytic hardwoods. Oak reproduction suitable for prescribed burning will typically be >1 foot tall with root collar diameters of at least 0.5-inch diameter (Brose and Van Lear 2004). Density of such oaks needs to range from several hundred to several thousand stems per acre with the larger densities needed on high-quality sites. Adequate oak density at this stage also varies by management objectives for future oak stocking at maturity. It also depends on the ability to do additional treatments at critical stand developmental stages such as crop tree release at canopy closure. Spatial distribution or stocking of the oak reproduction needs to be widespread throughout the stand so that at least 50 percent of the inventory plots contain this viable oak reproduction. On better quality sites, reproduction of the competing mesophytic hardwoods will often outnumber (by several thousand stems) and overtop (by several feet) the oak reproduction. When oak shelterwoods and final harvest stands have these two characteristics, they are candidate stands for prescribed burning to release the oak from competition. It should be noted that if vigorous oak reproduction is not overtopped and outnumbered by mesophytic hardwoods, then release burning is not necessary. However, this situation may only occur on low-quality sites.

The Shelterwood-Burn Technique

Correctly implementing the shelterwood-burn technique (Brose and others 1999a, 1999b) is more than simply applying fire to a partially cut oak stand. The proper application of the technique actually begins before the shelterwood harvest, while the stand is still uncut or has had a low/midstory shade reduction treatment. The first step addresses two questions: (1) is there enough oak reproduction at this time to proceed with a regeneration sequence given the future oak stocking goal, site quality, and obstacles to stand renewal, and (2) will the stand be able to be burned in approximately 5 years (fig. 2)? If the first question is answered negatively, then you must wait to implement the shelterwood-burn technique until there is an adequate density of oak reproduction or institute underplanting to reach the desired density of oak reproduction (Dey and Parker 1997a, 1997b; Johnson and others 2009). You may also consider the appropriateness of implementing a seedbed preparation burn (Brose and others 2014, Schuler and others 2013). If the second one is answered negatively, then you must make alternative regeneration plans such as using the Loftis shelterwood method, which is largely a removal of the midstory and overstory trees in the lower crown classes by mechanical or chemical methods

Figure 1—Shelterwood stands (left) and newly regenerated stands (right) are appropriate for release burning. (photo by Patrick Brose, USDA Forest Service)

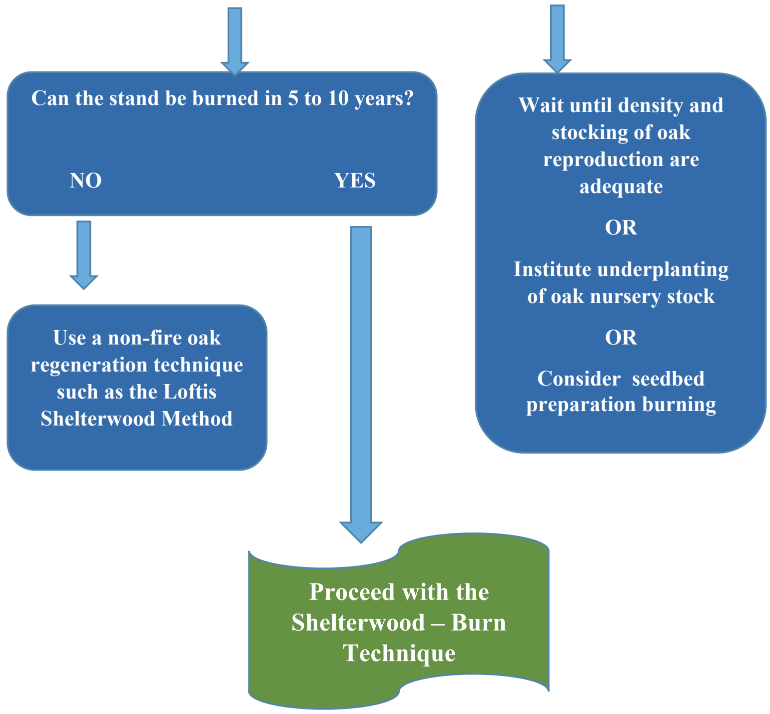

Figure 2—Decision-tree flowchart illustrating the questions that must be answered before implementing the shelterwood-burn technique. (photo by Patrick Brose, USDA Forest Service)

to promote the growth of the abundant but small oak advance reproduction (Loftis 1990). If both questions are answered positively, then proceed with the technique by planning and conducting the first removal cut of a two-stage shelterwood sequence.

The purpose of the first removal cut is to create the understory light conditions to promote rapid root development of the oak reproduction while not causing rapid height growth of the competing mesophytic regeneration (fig. 3, Brose 2011a). Because fire will be used in a few years, planning and conducting this harvest require some extra attention. First, lay out the access roads and skid trails so they can double as fire control lines in the future. This will expedite the preparation for the prescribed fire, decreasing one of its costs. Second, create a 50-percent open canopy by harvesting the low-quality stems, undesirable species, and some financially mature trees. This is more than a commercial harvest. It is necessary to remove unmerchantable overstory trees in the lower crown classes and any midstory trees to achieve this level of light. Fell unmerchantable trees and larger saplings, especially those >3 inches diameter at breast height (dbh), because they have higher probabilities of surviving a low-intensity fire intact. The cut stems have a high likelihood of sprouting, but the sprouts will be susceptible to topkill in a subsequent burn. Alternatively, the midstory and noncommercial trees can be stem injected with herbicides (Kochenderfer and others 2012).

Figure 3—Eight-year-old chestnut oak seedlings grown in shelterwoods of varying residual relative densities. Those on the left were in 70- to 90-percent relative density while those on the right were in 20- to 50-percent relative density. (photo by Patrick Brose, USDA Forest Service)

In terms of basal area, the residual will range from 50 to 80 square feet per acre with the higher residual levels being left on the better quality sites. The ideal leave trees are healthy, vigorous, high-quality oaks that are approximately 15 to 17 inches dbh. Trees of this diameter will increase substantially in size and value over the next 5 to 10 years, especially if they move from Grade 2 sawlogs to Grade 1 (Hanks 1976, Miller and others 1986) and will resist the formation of epicormics branches (Miller and Stringer 2004). It is unlikely that there will be enough ideal oaks per acre to meet the residual basal area guideline so other trees will have to be kept as leave trees, but be sure not to keep any undesirable species that are prolific seed producers such as black birch (*Betula lenta* L.) and yellow-poplar (*Liriodendron tulipifera* L.). Finally, manage the slash to protect the residual crop trees. The harvest will create concentrations of slash and such "fuel jackpots" within 10 feet of the bases of residual crop trees will create and hold an intense fire that will likely damage or kill them (Brose and Van Lear 1999). Be sure the logging contract stipulates that directional felling is used to prevent placing tree tops near the bases of residual crop trees or such slash is removed as part of the harvesting operation (Brose 2009b).

The first removal cut is followed by a multi-year waiting period of 4 to 7 years. This period is important for several reasons. First and foremost, this is when the oak reproduction develops root systems, a necessary precursor to the ability to vigorously sprout post-fire (Brose 2008, 2011a; Brose and Van Lear 2004). The wait also allows the seed bank in the forest floor to germinate, at least in part (Schuler and others 2010). The resultant flush of new reproduction probably will contain some seedlings that are potential long-term competitors to oak such as black birch and yellow-poplar. As new seedlings, these are virtually defenseless against a prescribed fire. Additionally, this wait allows the fuel bed to develop as the logging slash settles and dries and leaf litter accumulates from the residual canopy trees. Finally, the waiting period allows the residual crop trees to increase in volume and value, making the upcoming final harvest more profitable. Leave the stand undisturbed until the oak seedlings have root collars at least 0.50-inch diameter and are shorter than the competing mesophytic hardwood reproduction by 2 or more feet. These conditions will usually develop within 4 to 7 years, depending on site quality.

The purpose of the prescribed fire is to select for the oak seedlings and against the mesophytic hardwood reproduction based on the difference in resource allocation strategies between the two species groups – oaks concentrating resources on root development and mesophytic hardwoods on stems and branches. To do this, a hot spring burn is the optimal combination of fire intensity and season-of-burn for maximum benefit to the oak seedlings (Brose 2010, Brose and Van Lear 1998, Brose and others 1999a). Because such a fire will occur in an oak shelterwood, careful planning is essential. First, use Fuel Model 06 or 10 to represent the fuel loadings of oak shelterwoods in predicting expected fire behavior (Anderson 1982, Brose 2009a). Second, identify the residual crop trees in danger of fire damage due to logging slash close to their bases and take preventative measures to protect them (Brose 2010). Third, strive to burn at the ideal time in the spring season when the mesophytic hardwood reproduction has expanded leaves at least 50 percent, but the oak seedlings still have closed buds and the overstory is still dormant. This "sweet spot" varies by location and elevation from year to year. For example, this optimal burn window generally occurs in southern Ohio in late April, but is in mid-May in northern Pennsylvania. An extended winter or early spring will delay or move forward this window in the calendar as well as shorten or extend its duration. Finally, prescribe a hot surface fire. Flame lengths need to be at least 2 feet with rates of spread ranging from 3 to 7 feet per minute (fig. 4). Although this combination of fire intensity and season-of-burn has consistently produced excellent results in shifting the composition of the regeneration pool towards oak, burning outside the hot mid-spring window will also benefit oak but to a lesser degree (Brose 2010, Brose and others 2014). Cooler fires and those conducted earlier in the spring will provide less control of competing mesophytic hardwoods, and burns done after leaf expansion of the oak reproduction will reduce survival and decrease post-fire height growth.

When done properly, the shelterwood-burn technique will provide several benefits to the oak reproduction (Brose 2010, Brose and Van Lear 1998, Brose and others 1999a, Fenwick and others 2016). Well-timed surface burns will kill more mesophytic hardwood regeneration than oak reproduction, thereby increasing the relative abundance of oak in the advance regeneration pool (fig. 5). Sprouting oaks will improve in stem form and rate of height growth. Nutrients stored in the leaf litter and slash will be released back into the forest floor for subsequent use by the sprouting oaks (Blankenship and Arthur 1999, Boerner 2000). The ectomycorrhizae in the forest floor will be stimulated (Stottlemyer and others 2013). Berry-producing shrubs such as blueberry (*Vaccinium* spp.), huckleberry (*Gaylusscia* spp.), and blackberry (*Rubus* spp.) will be reinvigorated or germinate from seed stored in the forest floor. Besides the food benefit to wildlife, blackberry may help in development of oak sprouts as it slows the height growth of mesophytic hardwood seedlings (Donoso and Nyland 2006). It also provides an alternative supply of browse for deer and hiding cover for oak reproduction, potentially reducing deer browsing pressure on oaks.

Figure 4—A moderate-intensity spring fire in central Virginia. Flame lengths are 2 and 4 feet, (photo by Patrick Brose, USDA Forest Service)

Figure 5—The same stand shown in figure 4 but several weeks later. The dead saplings are yellow-poplar and red maple while the green sprouts are oak and hickory. The relative abundance of oak and hickory increased from 10 to 70 percent in the regeneration pool, and this dominance continued as the new stand grew into saplings. (photo by Patrick Brose, USDA Forest Service)

Based on our collective experience, we see six common mistakes committed by land managers implementing the shelterwood-burn technique. They are:

1. Making the first removal cut before adequate oak seedlings are established.
2. Not creating at least 50 percent open canopy with the first removal cut.
3. Not preventing slash accumulations near the bases of residual crop trees or not mitigating this situation prior to burning.
4. Not waiting long enough for the oak reproduction to develop roots and be overtopped by competing mesophytic hardwood regeneration.
5. Burning earlier in the spring than is recommended.
6. Not conducting a moderate- to high-intensity fire.

Committing any of these mistakes will likely necessitate additional prescribed fires or other silvicultural treatments to regenerate oak and avoid undesirable results at the end of the regeneration process.

The shelterwood-burn technique does have some drawbacks. The residual crop trees are at risk for fire damage and mortality (Brose and Van Lear 1999, Wiedenbeck and others 2017). This risk is real as well as perceived. Even though a veneer-quality oak is not damaged by the fire, potential buyers may pay less money for it because of the threat of staining. Larger red oaks (>11 inches dbh) scarred by fire can lose up to 10 percent of value in the butt log within 15 years of burning (Marschall and others 2014). The fire will kill small oak reproduction that has not yet developed large enough root systems necessary for vigorous post-fire sprouting (Miller and others 2017). If native and nonnative invasive plant species are in the burn unit, they may expand in coverage or they may seed in from adjoining areas (Rebbeck 2012). Deer are attracted to burned areas because the sprouting hardwoods are especially palatable and nutritious. Mid-spring prescribed fires are probably disruptive to ground-nesting birds such as ruffed grouse (*Bonasa umbellus*), wild turkey (*Meleagris gallopavo*), and several species of neotropical songbirds and are potentially lethal to herpetofauna just emerging from winter hibernation (Beaupre and Douglas 2012). Indeed, in some States or within some agencies, burning in the mid-spring period is not permitted due to endangered species regulations.

Post-Harvest Burning

One approach to mitigating the fire damage risk to crop trees in the shelterwood-burn technique is to conduct the final removal harvest before implementing the burn. This alternative is called post-harvest burning (and mimics the early-20th-century disturbance regime that produced many of the current oak stands (Hutchinson and others 2008). If more time is needed for oak seedlings to get bigger before burning, the overstory harvest itself may provide a short-term release of the oak reproduction. Therefore, burning may be delayed for 1 to 3 years depending on site quality, and should be done before the height of the woody competition exceeds the oak reproduction by >2 feet and average stem dbh increases to >3 inches. Post-harvest burning has much in common with the shelterwood-burn technique. Both have the same objectives and prerequisites. Post-harvest burning should be done in mid-spring and strive for the same fire intensity as in the shelterwood-burn methods. One difference is in planning. Post-harvest burning has considerably higher fuel loads, 30 to 40 tons per acre, so AFM 12 should be used in place of AFM-06 or 10 (Brose 2009a). Anticipate flame lengths in excess of 5 feet (10 to 15 feet is not unusual) and a large smoke column and plan accordingly for containment resources and smoke dispersal strategies. Post-harvest burning is not common in the scientific literature, but the existing publications indicate that the oaks in the regeneration pool are benefitted by fire at the end of the regeneration process (Carvell and Maxey 1969, McGee 1980, Ward and Brose 2004, Ward and Stephens 1989). Recent research confirms the findings of these studies (fig. 6, Brose 2013).

A somewhat different approach to post-harvest burning is the fell-and-burn technique (Abercrombie and Sims 1986, Phillips and Abercrombie 1987). This method originated in the southern Appalachian Mountains and upper Piedmont regions in the 1980s to regenerate or create pine-oak stands on low-quality sites (fig. 7). As the name suggests, this technique is a multi-step process. First, all the merchantable trees of the existing stand are harvested. This is generally done in the winter. In the following spring, once the leaves are well- to fully developed, all the non-merchantable stems are felled. Once their foliage is cured and their twigs and small branches dry, the site is broadcast burned. This prescribed burn is conducted during the first summer following harvesting and slashing and after the hardwood stumps have sprouted, but within 1 to 2 days after a soaking rain. This fire reduces the fuel loading, slows the height growth of oak and other hardwood sprouts, and prepares the site for the final step – planting of pine (*Pinus* spp.) seedlings. This planting takes place during the following winter and the pines are planted at a fairly wide spacing (15 x 15 feet or greater). The preferred pine species varies by locale – loblolly (*Pinus taeda* L.) in the Piedmont, shortleaf *(P. echinata* Mill.) in the Ozarks, and pitch (*P. rigida* Mill.) and eastern white (*P. strobus* L.) in the Appalachians. Long-term research of this technique shows that the pine seedlings initially lag behind the hardwood sprouts in height growth, but become dominant by year 7 to 10 (Waldrop 1997). By

Figure 6—A 5-year-old post-harvest burn stand in northern Pennsylvania. Post-harvest burning appears to create new, oak-dominated stands much like the shelterwood-burn technique. (photo by Patrick Brose, USDA Forest Service)

Figure 7—A young mixed oak-pine forest in western South Carolina created by the fell-and-burn technique. Note the diversity of tree species as indicated by their different fall colors. (photo by Thomas Waldrop, USDA Forest Service)

year 20, this method results in a mixed-species stand dominated by two species groups: oaks and pines (Waldrop and Mohr 2012).

CONCLUSION

Using prescribed fire as a silvicultural tool, where timber values are expected to be retained, requires more consideration than returning fire as an ecological component to a forest. Oak reproduction must be assessed before using fire. Burn prescriptions must mesh with silvicultural prescriptions. Common mistakes must be avoided. However, if the guidelines presented here are followed and the common mistakes avoided, prescribed fire can be successful in the oak reproduction process.

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