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ECOLOGY AND MANAGEMENT *of* OAK WOODLANDS AND SAVANNAHS

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WHAT ARE OAK WOODLANDS AND SAVANNAHS?

Oak woodlands and savannahs are a successional transition between prairies and forests (Nelson 2010). A sparse overstory of fire-tolerant oak trees distinguishes these communities from prairies and allows sufficient sunlight to reach the ground layer. This sunlight is essential for the development of an understory dominated by grasses and flowering plants, a key characteristic not present within closed-canopy forests (Table 1).

The existence of oak woodlands and savannahs has always been strongly linked to the historical frequency of fires that resulted from lightning or were set by Native Americans (McPherson 1997). Without the regular occurrence of fire, woodlands and savannahs will follow natural succession and become closed-canopy forests. Frequent fire that occurs over many decades can eliminate woody vegetation and create prairie.

Oak woodlands and savannahs once dominated the transitional zone between the Great Plains and more mesic deciduous forests of the eastern U.S. (Figure 1). Within this region, soil characteristics and landscape position influenced their distribution. Oak savannahs were more common on southwest slopes and along ridges where drier conditions produced more intense and frequent fires. They were also common where excessively well-drained or shallow soils limited tree growth through reduced nutrients and moisture. Oak woodlands typically occurred on slightly more mesic sites and lower slope positions than savannahs.

From west to east, widely spaced trees gradually became more common, whereas understories retained the rich grass and forb diversity typical of the open prairie. Closer to the forests of the east, trees became more dominant and savannahs transitioned into woodlands and then to closed-canopy forest.

Moving from north to south, overstory pine components within oak woodlands and savannahs gradually increased. At the southern limit of glaciation, this pine component diminished markedly.

Oak woodlands and savannahs also occur on the West Coast and in southwestern North America. While some characteristics and restoration techniques may overlap, this publication specifically addresses eastern oak savannahs and woodlands.

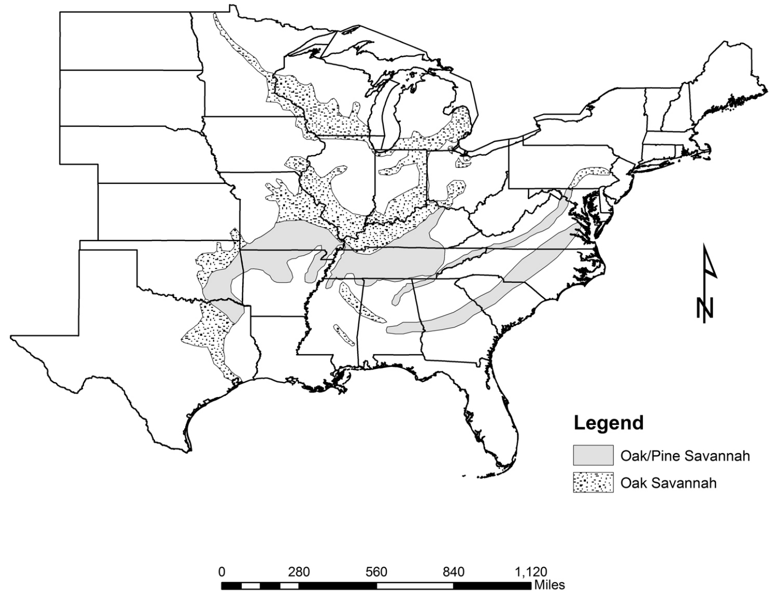

FIGURE 1. (above right) Approximate distribution of presettlement oak and oak/pine savannahs in central North America. Adapted from Haney and Apfelbaum (1993) and Henderson and Epstein (1995).

WHY ARE THEY IMPORTANT?

Oak savannahs are one of the most imperiled plant communities in North America. Once covering 32 million acres, their decline since European settlement has exceeded 99 percent (Nuzzo 1986). Such drastic loss has occurred in response to fire suppression and conversion to agriculture. Land development, unrestricted grazing by domestic livestock and introduction of aggressive, non-native forage grasses also have contributed.

These parklike environments were aesthetically pleasing (Figure 2) and benefited a wide array of plant and animal species. Their diverse and complex structure allowed both early- and late-successional species to thrive simultaneously. The full crowns of open-grown oaks produced plentiful acorns that provided food for many wildlife species. Oak woodlands and savannahs are critically important for declining red-headed woodpeckers (*Melanerpes erythrocephalus*) (Figure 3), a woodland/savannah obligate.

The majority of birds experiencing population declines in the eastern U.S. are disturbance-dependent, and the loss of oak woodlands and savannahs has contributed to these trends (Hunter et al. 2001). This loss includes grassland and shrubland species as well as late-successional species that require moderate forest disturbance (e.g., cerulean warbler, *Dendroica cerulea*). Restoration efforts have been shown to benefit many of these open-canopy associated species (Davis et al. 2000). Research at the University of Tennessee Institute of Agriculture has shown that moderate canopy disturbance promotes the presence of disturbance-dependent birds while mitigating negative effects on mature forest species (Figure 4).

TABLE 1. Vegetation characteristics along the prairie to forest transition. These distinctions vary slightly by authority and are not rigid definitions.

VEGETATION TYPE	CANOPY COVER (%)	LIVE BASAL AREA (FT^2 $ACRE^{-1}$)	HERBACEOUS GROUND-LAYER DOMINANCE
Prarie	<10	<10	Yes
Savannah	10-30	10-40	Yes
Woodland	30-80	45-65	Yes
Forest	80-100	>65	No

FIGURE 2. Oak savannah (left) with a sparse oak overstory and lush, herbaceous understory (Photo courtesy of A. Vander Yacht) and an oak woodland (right) with a substantial herbaceous ground layer under greater canopy cover (Photo courtesy of C. Coffey).

Many bat species face catastrophic declines as a result of a fungal infection known as white-nose syndrome (WNS). Considering the lack of direct strategies for combating this threat, increasing bat habitat quality could assist in population persistence and aid species recovery. The open canopies of woodlands and savannahs provide improved foraging conditions for bats, allowing bats to develop greater energy reserves prior to entering hibernation and thus mitigating the effects of WNS (Cox et al. 2016).

Many Lepidoptera associated with woodlands and savannahs are endangered. This includes species like the Karner blue butterfly (*Lycaeides melissa samuelis*) (Figure 5), which is restricted to oak openings and uses sundial lupine (*Lupinus perennis*) as a larval host (Shuey et al. 1987). In addition, many rare and endangered species of herpetofauna respond positively to increased canopy openness and the effects of fire during oak woodland and savannah restoration (Engstrom 2010, Wilgers and Horne 2006).

Oak woodlands and savannahs provide high-quality habitat for many game species. They are nearly ideal for wild turkey (*Meleagris gallopavo*). Open-grown oaks are excellent roost sites, and their acorns are a dependable and preferred food source. Understory vegetation is thick enough to conceal nests but low enough to allow hens to survey surroundings. The prairie-like vegetation also supports an abundance of insects, which are a vitally important food source during brood-rearing. In addition to acorns, abundant forage for white-tailed deer (*Odocoileus virginianus*) exists within the understory. Squirrels and rabbits are also common.

Herbaceous plant diversity in oak woodlands and savannahs included as many as 300 species of legumes, forbs and grasses and was greater than that found in either prairies or forests. Many of these species have become imperiled, including purple milkweed (*Asclepias purpurascens*) (Figure 6) and Atlantic camas (*Camassia scilloides*) (Cochrane and Iltis 2000). The high herbaceous diversity is the result of understory plant resource gradients that radiate outward from the boles of overstory trees, creating microclimates conducive to many different species. As early successional communities, woodlands and savannahs have high net productivity benefitting multiple trophic levels.

FIGURE 3. (below) Red-headed woodpecker in an oak savannah. (Photo courtesy of S. McIntire)

FIGURE 4. (right) Trends in occupancy for a mature forest species (ovenbird) and an early-successional species (prairie warbler) across variation in live basal area. Canopies with 40 ft^2 ac^{-1} maximize prairie warbler presence while retaining ovenbird presence. (Adapted from Vander Yacht et al. 2016)

FIGURE 5. (below) Karner blue butterfly. (Photo courtesy of Catherine Herms, The Ohio State University, Bugwood.org)

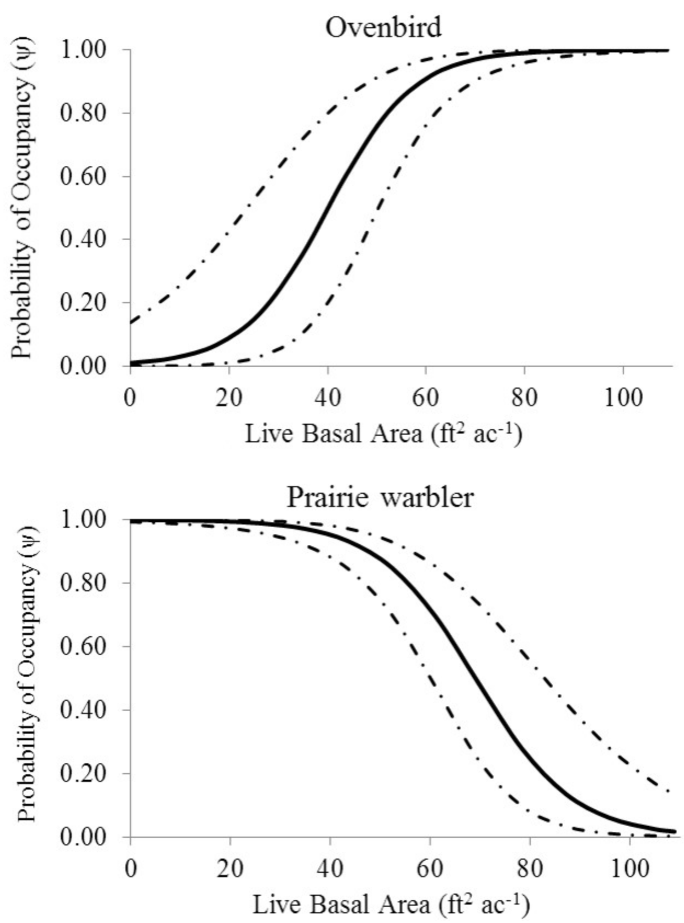

FIGURE 6. Purple milkweed is rare now but is often found in restored oak savannahs. (Photo courtesy of pleasantvalleyconservancy.org)

SPECIES COMPOSITION

The individual species that dominate the overstory of oak savannahs vary by geography and available moisture. On drier sites and along the western edge of the range of oak savannahs, blackjack (*Q. marilandica*) and post oak (*Q. stellata*) are often dominant. To the north, where savannahs often occur on sandy soils, black (*Q. velutina*) and northern pin oak (*Q. ellipsoidalis*) are common.

On sites with more moisture and where clay-loam soils are common, bur oak (*Q. macrocarpa*) dominates; such sites tend to have the highest plant diversity among savannahs. On floodplain sites with alluvial soils, savannahs are dominated by bur and white oaks (*Q. alba*). Other mesic site species include northern red (*Q. rubra*), black, northern pin and swamp white oak (*Q. bicolor*) (Haney and Apfelbaum 1993).

Historically, pines were common within the southern portions of the oak savannah and woodland range (Figure 1). On the southern and eastern fringes of the oak woodland/savannah ecosystem, longleaf (*Pinus palustris*) and, to a lesser extent, loblolly (*P. taeda*), would have occurred. Shortleaf pine (*P. echinata*) was a common associate with overstory oaks throughout its range (generally, south of the Ohio and Missouri Rivers). It is likely that most woodlands and savannahs in this region were a mixture of oak and pine.

Herbaceous species within oak woodlands and savannahs (Figure 7) include many fire-adapted (pyrophytic) grasses, which often dominate the herbaceous layer. Common species include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), broomsedge (*Andropogon virginicus*), silver plumegrass (*Saccharum alopecuroides*), and poverty oatgrass (*Danthonia spicata*).

A diversity of legume species also occurs within the understory, including ticktrefoil (*Desmodium spp.*), partridge pea (*Chamaecrista fasciculata*), roundhead lespedeza (*Lespedeza capitata*), slender lespedeza (*L. virginica*), Illinois bundleflower (*Desmanthus illinoensis*), sensitive briar (*Mimosa microphylla*), and purple prairie clover (*Dalea purpurea*).

Many other forbs, including Black-eyed Susan (*Rudbeckia hirta*), woodland sunflower (*Helianthus divaricatus*), goldenrods (*Solidago spp.*), blazing stars (*Liatris spp.*), and wild bergamot (*Monarda fistulosa*) are all common, although the exact composition of the savannah understory varies by region.

While the frequent fires that maintained these systems would have eliminated most of the midstory, some shrubs and brambles, such as blueberries (*Vaccinium spp.*) and blackberries (*Rubus spp.*), would have persisted. Similarly, some of the other fire-tolerant hardwood species, such as the hickories (*Carya spp.*), blackgum (*Nyssa sylvatica*), and common persimmon (*Diospyros virginiana*), would have been present, although much less prominent than the oaks.

FIGURE 7. The herbaceous layer of oak woodlands and savannahs consists of fire-adapted grasses like big bluestem (left), legumes like sensitive briar (middle), and other forbs like blazing star (right). (Photo courtesy of A. Vander Yacht)

FIGURE 8. Recent timber harvest in preparation for savannah restoration. Note the large amounts of slash that will contribute to fuel loads and lack of herbaceous ground layer. (Photo courtesy of P. Keyser)

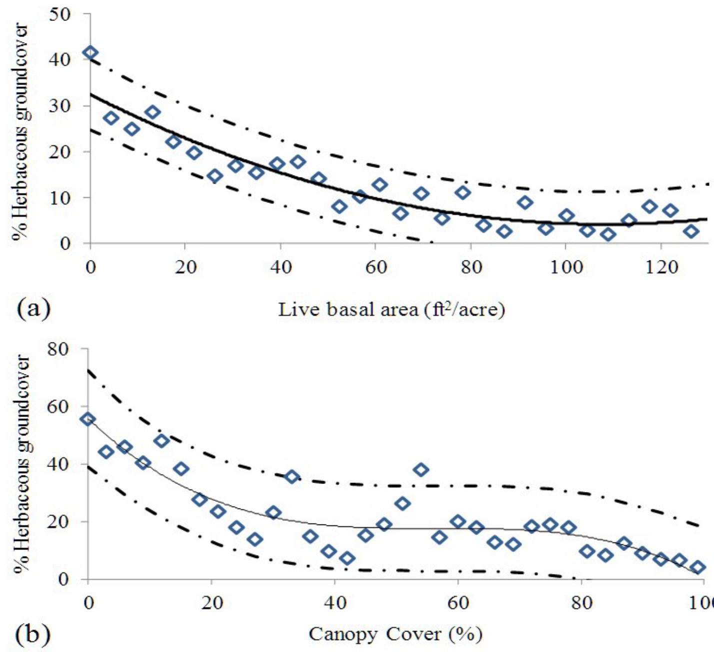

FIGURE 9. Herbaceous layer development is strongly influenced by overstory structure. Herbaceous groundcover increases after the overstory is reduced (a) below 60 square feet per acre (woodland target). Further increases occur once canopy cover is reduced (b) below 30 precent (savannah target). As herbaceous cover increases, herbaceous richness and diversity increase as well.

RESTORING AND MAINTAINING OAK WOODLANDS AND SAVANNAHS

In nearly all cases, restoration begins with reducing a dense forest canopy to levels typical of historic woodlands or savannahs (Nielsen et al. 2003) (Table 1). This initial step can be accomplished quickly, particularly if commercial timber harvesting is an option. The second critical step involves restoration of the understory, which requires reintroducing a periodic, low-intensity fire regime similar to that which originally created and maintained such communities. These two primary restoration activities — thinning and burning — need to be considered initially when choosing a restoration site.

CHOOSING A SITE

Dry, low-quality sites are better suited for restoration; historically, they burned more frequently and likely contain many desirable plants within the seedbed. More mesic, productive sites (floodplains, riparian areas, coves and northern slopes) would have burned less frequently and are best left to timber production. Avoiding such sites reduces the density and vigor of woody midstory vegetation that develops in response to canopy disturbance, making restoration more difficult. Sites with remnant grasses and forbs are also preferred for restoration. Evaluating overstory tree and understory plant species composition can provide a good measure of a site's suitability for restoration and eliminate the need for costly planting efforts.

Within suitable sites, those with mature trees are easiest to restore because commercial timber harvesting can be used to open the canopy. The thicker bark of mature trees also makes them more resistant to fire. If access to a site is limited, the placement of roads should consider their potential use as future firebreaks.

For both harvesting and burning, the size of the site is an important consideration. Small tracts with irregular boundaries have a higher risk of fire escape and higher cost per unit area. Tracts less than 25 acres may not contain enough timber to make commercial harvests feasible. Larger tracts more easily accommodate thinning and burning and provide greater benefits to wildlife species associated with early successional habitat.

OPENING THE CANOPY

Prior to opening the canopy, invasive plant populations should be located and identified. Invasive species can outcompete desirable native species, suppress their germination, degrade structure, and alter fuel loads. Controlling invasives before opening the canopy is more effective and efficient (Brock 2004). Japanese stiltgrass (*Microstegium vimineum*), miscanthus (*Miscanthus sinensis*), honeysuckle (*Lonicera spp.*), autumn olive (*Elaeagnus umbellate*), multiflora rose (*Rosa multiflora*), kudzu (*Pueraria sp.*), buckthorn (*Rhamnus cathartica*), and prickly ash (*Xanthoxylum americanum*) are invasives that occur under canopies and can interfere with successful restoration. Johnsongrass (*Sorghum halepense*), tall fescue (*Lolium arundinaceu*m), bermudagrass (*Cynodon dactylon*), and sericea lespedeza (*Lespedeza cuneata*) are invasives that are not likely to occur under intact canopies but may quickly invade from nearby roads or fields. For woody invasives, cut-stump and foliar herbicide applications can be very successful, although repeated applications may be necessary to control resprouting. Foliar herbicide applications work well on herbaceous invasives.

If the site chosen for restoration can support a commercial timber harvest, opening the canopy simply involves conducting a timber sale. Marking removal or leave trees is very similar to a seed tree or heavy shelterwood cut (Figure 8). Targeting woodland and savannah basal areas (Table 1) will open the canopy enough to allow herbaceous groundcover to respond to the increased sunlight (Figure 9). It is prudent to err on the high side of these targets, as additional mortality after thinning due to stress, wind-throw, ice or ensuing prescribed fires is likely. Variation in basal area within stands is desirable, as it creates a diversity of microsite conditions capable of supporting an equal diversity of plant and wildlife species. In addition, basal area targets can be modified by specific site conditions to achieve desired effects.

Selecting trees to retain is first governed by species, with sound and vigorous fire-tolerant oaks being favored. Where the typical savannah oaks are absent, fire-tolerant hickories and blackgum and

FIGURE 10. Fire is a critical element in restoring and maintaining oak woodlands and savannahs. (Photo courtesy of A. Vander Yacht)

less fire-tolerant oaks, such as southern red (*Q. falcata*) and northern red, can be retained. Shortleaf and other fire-tolerant pines can also be retained where they still occur. All fire-intolerant species, including maples (*Acer spp.*) and yellow poplar (*Liriodendron tulipifera*), should be removed. Their prolific seeding will continually reintroduce woody vegetation to the understory, negatively affecting the desired herbaceous ground layer. Any trees of high value (veneer and grade lumber) should be removed to prevent lost revenue from fire damage. Hollow or damaged trees can be removed based on their fire susceptibility, but consideration should be given to their high value to wildlife, such as cavity-nesting birds and bats.

If a younger stand without commercial harvest potential has been chosen, undesirable trees are best killed and left standing by girdling and spraying the wound with herbicide. Felling and treating stumps drastically increases fuel loads, severely increasing the intensity of subsequent prescribed burning. Standing dead snags break down gradually over time and provide good wildlife habitat while doing so. Exceptions to leaving snags would include areas adjacent to fire lines. An alternative to fell-and-leave would be pile-and-burn brush piles, but it is labor-intensive and expensive (Brock 2004).

REINTRODUCING FIRE

The reintroduction of fire is critical for woodland and savannah restoration because it controls hardwood and shrub midstory while promoting grasses and forbs (Figures 10 and 11) (Peterson and Reich 2001). The initial burn following canopy disturbance is often more intense than subsequent burns because of elevated fuel loads, but this intensity is needed to reduce woody competition. Waiting two years after thinning to burn allows sprouts from hardwood rootstocks and newly germinated woody plants to grow just to the point of being very vulnerable to fire.

The return of fine fuel layer continuity after logging disturbance and the degradation of heavy logging slash will also occur during this period. Where fuel loading is very high, waiting an additional year, manual fuel reduction, and/or planning for a less intense fire (moister, cooler conditions) may be warranted. However, waiting more than three or four years is not advised because woody regrowth may reach a stage beyond the effective control of fire.

Generally, the first two or three fires should be conducted as growing-season burns, preferably from mid-August to late September, because hardwood rootstocks are best controlled during this time. Many of these rootstocks are large, having developed over many years, and will not be controlled completely with one or two fires. The use of growing-season fires at a two-year interval initially will yield the best hardwood control and prevent the woody vegetation from dominating the understory.

Growing-season fire will also promote the desired pyrophytic grasses that are important to the understory structure and maintenance of the fine fuel layer. In cases of very high fuel loading, growing-season burning conditions should be chosen carefully to ensure a low-intensity fire. Removal of slash from the base of trees and possibly even conducting initial winter fuel-reduction burns may be warranted to reduce the risk of fire escape or damage to overstory trees (Hartman 2001).

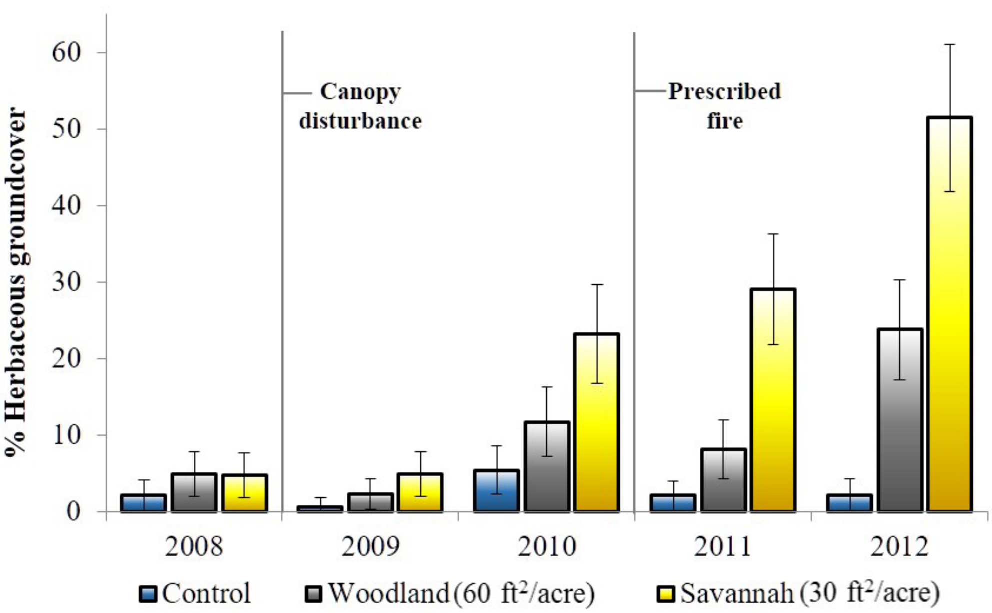

FIGURE 11. The effects of canopy disturbance and fire on herbaceous groundcover during a restoration experiment at Catoosa Wildlife Management Area (2008-2012). Herbaceous groundcover increased by the second year post-canopy disturbance and again by the second year post-fire, and such increases were greater under more heavily disturbed canopies. (Courtesy of A. Vander Yacht)

MAINTENANCE BURNING AND OAK REGENERATION

As the woody vegetation is controlled through a series of fires, the burning cycle should be alternated to include dormant-season fires. Although they do not control hardwoods as well, dormant-season fires are important in promoting a number of cool-season herbaceous species. These winter burns are often easier to implement because weather conditions are typically more conducive to low-intensity fires. Over time, selecting the burning season should balance the needs for controlling woody competition and for encouraging the growth of legumes and other cool-season plants. Fire intensity should remain moderate to low once the initial fires have been conducted and the woody species have been reduced to manageable levels. Thereafter, long-term maintenance of the oak savannah is dependent on the periodic disturbance provided by an appropriate fire regime. On drier sites and in areas with less rainfall, fire frequency may only need to be once every three to four years. Where soils have higher clay contents and hold water longer, sites are wetter, or rainfall is greater, fires may need to occur once every two years.

At some point, encouraging oak recruitment (and pine) into the overstory will be necessary to perpetuate woodlands and savannahs. In many cases, varying the frequency of burning will allow a certain amount of advanced regeneration to survive. If not, protecting some desirable well-established regeneration from prescribed fires may be necessary until it is large enough to survive on its own (generally 3-4 inches in diameter at breast height). Suspending the burning regime altogether for a short period of time (three to 10 years) may be necessary to establish adequate regeneration. This should not be attempted until the more aggressive, fire-intolerant species have all but been eliminated. Excluding smaller sections of the entire unit from fire for this purpose and rotating through the area over time will help to stagger age classes and the distribution of the regeneration. Remember that the desired canopy is quite open, so successful regeneration may require only about 50 trees per acre. Proper management of the newly established ecosystem is critical in maintaining it in the desired state.

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