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Fell-and-Burn Site Preparation to Establish Pine-Hardwood Mixtures

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INTRODUCTION

Managed pine-hardwood mixtures on suitable sites in the Southeast offer landowners' opportunities to meet multiple management objectives. These forest types consist of 25-75% stocking, basal area, or trees per acre of pines (one or multiple species) while having one or more hardwood species that comprise the remaining growing stock (Sheffield et al. 1989). Pine-hardwood silviculture is considered a hands-off approach to forest management in comparison to pine plantations. Managing for pine-hardwood mixtures may be attractive to landowners who fit one or more of the following criteria:

- own smaller acreages (usually 100 acres or less),
- are not as interested in intensive management (pine plantations),
- need a low-cost alternative to more intensive management,
- tend to be risk-averse (e.g. southern pine beetle infestations in pine plantation),
- want to develop or maintain a mast component for wildlife, and
- individuals more inclined to promote increased diversity of their forests from a biological and/or economic standpoint.

In addition, recent research investigating climate adaptability and resiliency of shortleaf pine-oak mixtures has shown that these mixtures are likely to be more resilient to increasingly erratic weather associated with climate change than single species conifer and mixed hardwood stands that occur on similar sites in the region (Kabrick et al. 2017). These characteristics might also apply to other pine-hardwood forest types in the Southeast. Primary drawbacks to pine-hardwood management include less productivity in terms of growth and yield (especially for pine), increased risk of certain insects and pathogens (primarily pine sawflies and fusiform rust with unimproved loblolly pine genetics), greater management complexity, and pine and hardwood timber markets often must be located nearby to enable pine-hardwood management. More thorough overviews on rationale for managing for pine hardwood-mixtures are given in Waldrop (1989), Willis et al. (2019) and Clabo et al. (2020).

In terms of forest development, pine-hardwood forest types are successional or transitional between pure or nearly pure pine and climax mixed hardwood forests. Throughout many areas of the Southeast, these forests develop from abandoned or mis-managed pine plantations that through many years of no disturbance, are invaded by shade intermediate or tolerant hardwoods that gradually occupy a majority of the stand's stocking. Another developmental pathway is abandoned agricultural fields that first develop a pine component. Wind dispersed pine seeds from nearby mature trees and resultant seedlings initially dominate and occupy most of the growing space in the stand. Over time, in the absence of natural or human disturbance, hardwood encroachment occurs. Naturally regenerated pine-hardwood mixtures can be managed with prescribed fire and other tending operations but they do not offer landowners or managers an opportunity to manage stand stocking or density (pine only or pine and hardwood components). According to the most recent U.S. Forest Service Forest Inventory and Analysis (FIA) reports for ten southern states, pine-hardwood mixtures occur on over 19 million acres in the region, yet these stands are rarely intentionally managed. In Georgia for instance, the state's

most recent FIA report states that 2.731 million acres of pine-hardwood mixtures occur throughout the state, yet only 402,300 acres originated from either pine (mostly) or hardwood artificial regeneration (Brandeis et al. 2016) (Figure 1).

Most previous studies on pine-hardwood management have occurred in the Piedmont, southern Appalachian Mountains, and Interior Low Plateau physiographic regions of the Southeast. Establishment efforts have focused on introducing or planting a pine component on cutover sites (usually stands are clearcut to replace poor quality or poorly stocked mixed hardwood stands on upland sites) where pine seed sources may not be present and natural hardwood regeneration is allowed to develop among planted pines. Pines are usually planted at wider spacings than in traditional pine plantations to encourage hardwood development. Management sequences typically involve a harvest or precommercial operation to remove most standing woody stems during the spring, a moderate to high intensity site preparation burn during the summer, and planting of pine seedlings at wide spacings during the winter months. Herbicides are not typically used during site preparation unless invasive plants are present (e.g. Clabo and Clatterbuck 2020). Herbicides reduce hardwood stocking and result in a future stand with few or no hardwoods that is dominated by pines (e.g. Clabo and Clatterbuck 2015). Short and long-term reports (4 to 34 years) have documented good results across a variety of sites in terms of relatively even (basal area, trees per acre, etc.) mixtures of pines and hardwoods with the fell and burn method. In addition, fell and burn site preparation is cited as costing roughly half of typical pine plantation site preparation (e.g. Clabo and Clatterbuck 2015, 2020, Clinton et al. 1993, Phillips and Abercrombie, Jr. 1987, Pile and Waldrop 2016, Sims et al. 1981, Waldrop 1997).

Figure 1: ***A) Example of a naturally regenerated, mixed shortleaf pine-hardwood stand in the Georgia Piedmont. Most mixed pine-hardwood stands throughout Georgia and the Southeast regenerated naturally. B) An eight-year-old, artificially regenerated shortleaf pine-hardwood mixture located in the Appalachian or Cumberland Plateau region of northwestern Georgia. Pines were planted and hardwoods (primarily desirable oak species) developed naturally among planted pines in this stand.***

SITE SELECTION AND SPECIES COMPOSITION

Site selection is a critical step for successfully managing pine-hardwood mixtures. For best growth and development of pines and hardwoods, sites should not be so low in productivity that hardwoods are absent, grow slowly or have poor form. Conversely, high quality sites where hardwoods quickly outcompete pines for growing space and resources are not good choices for pine-hardwood management. In general, intermediate productivity sites are best for pine-hardwood management. Outside of the Lower Coastal Plain, pine-hardwood management is most suited to the climate and intermediate soil productivity sites on middle to upper slope positions throughout the Upper or Hilly Coastal Plain, Piedmont, Appalachian Mountain Foothills,

Ridge and Valley, and Cumberland Plateau physiographic regions. A classification system for determining sites most suitable for pine-hardwood management was produced during the late 1980s by researchers at Clemson University for Piedmont and Upper Coastal Plain sites (Jones 1989). For the Piedmont region, sites on mid- to lower slope positions and southern to western aspects are most likely to grow both quality pine and hardwood stems (e.g. oak spp.). Soils on these sites have clayey to sandy clay surface textures with a clay horizon (argillic or Bt horizon) within 12-24 inches of the surface. White oak, scarlet, and northern red oak are typical hardwood species associated with these site types. White oak site index is estimated to range from 80 to 90 feet at base age 50 years (Jones 1989) (Figure 2). In the Upper or Hilly Coastal Plain region, soils are primarily Typic Paleudults or Typic Hapludults. These soils are normal (not grading toward another soil type) ultisols that occur in moist, humid climates and either have extreme profile development characteristic of old soils ('Pale') or are more simple soils that have minimum horizonation ('Haplu'). These soils have a sandy textured horizon that is less than 20 inches thick that occurs on top of a predominately clay horizon (argillic or Bt horizon). Characteristic landforms include moderate to steep slopes at mid- to upper slope positions. Site index for loblolly pine usually ranges from 85-90 feet (Jones 1989) (Figure 3). Less information is available on suitable sites for pine-hardwood mixtures in other physiographic regions, but authors have suggested that sites with a site index between 65 and 70 feet (base age 50 years) for upland oaks may be most appropriate in other regions outside of the Piedmont and Upper Coastal Plain (Waldrop et al. 1989).

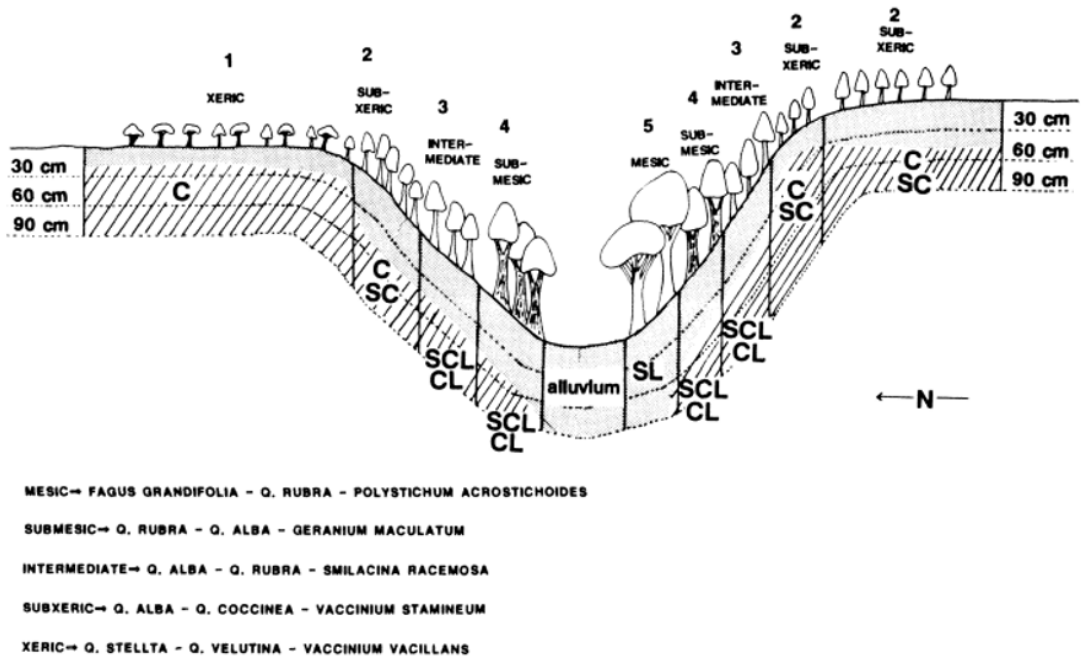

Figure 2: *Land type classification model integrating soils, vegetation and site characteristics are displayed for a typical Piedmont landscape. Results from this study determined that unit 3 'intermediate' would be most appropriate for pine-hardwood management (loblolly and/or shortleaf pine) (Jones 1989).*

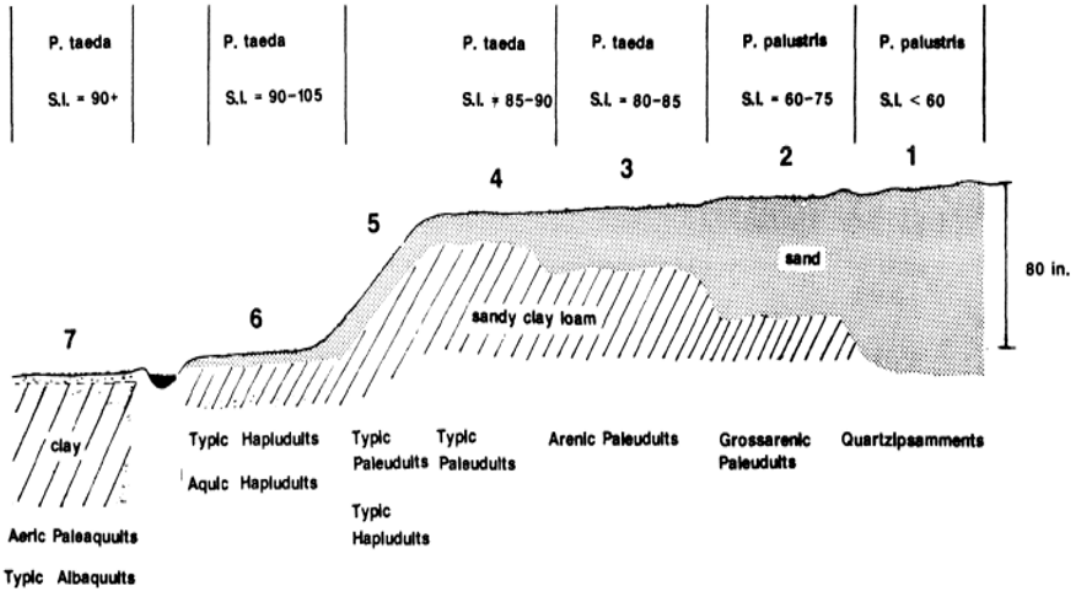

Figure 3: *Site index ranges for loblolly and longleaf pine across seven Upper Coastal Plain landscape ecosystem units. Results from this study determined that units four and five would be best for loblolly pine-hardwood management (Jones 1989).*

Species compositions in pine-hardwood mixtures vary widely by geographic location, climatic conditions, soils, and geology throughout the Southeast. The shortleaf pine-oak type (Society of American Foresters (SAF) Type 76) occurs throughout every physiographic region in the South below elevations of 2,000 feet. Virginia pine-oak (SAF type 78) occurs in the Piedmont, Appalachian foothills and Mountains (below elevations of 3,000 ft), Cumberland, Plateau, Highland Rim or Pennyroyal, and Ridge and Valley physiographic provinces. Loblolly pine-hardwood (SAF type 82) occurs predominately in the Upper or Hilly Coastal Plain, Piedmont and Appalachian foothills, but may also be found in the Ridge and Valley, Highland Rim or Pennyroyal, and Cumberland Plateau where loblolly pine is planted outside of its native range. Additional information on loblolly pine-hardwood forest type species compositions can be found in Clabo et al. (2019). In the Appalachian Mountains, the Eastern white pine-Northern red oak-red maple type (SAF type 20) may occasionally be present, but it has a much smaller extent in the Southeast than the other commonly encountered pine-hardwood types (Figure 4). For more information on constituent species in these types refer to Eyre (1980).

Figure 4: *Example of a naturally regenerated Eastern white pine-Northern red oak-red maple forest type (SAF type 20) in a low elevation (<2,500 ft) stand in the Blue Ridge Mountains of western North Carolina.*

HISTORY OF FELL-AND-BURN SITE PREPARATION TO ESTABLISH PINE-HARDWOOD MIXTURES

During the late 1970s, researchers with the U.S. Forest Service began to recognize a need for a low-cost management alternative to pine plantation establishment for private landowners who owned poor- quality, mixed hardwood stands on upland sites in the Piedmont and southern Appalachian Mountains. In the mid-1980s, FIA statistics showed that 65% of the roughly 39.5 million acres of commercial timberland in these regions were occupied by mixed hardwood or pine-hardwood forest types (Bechtold and Ruark 1988). Approximately 72% of this land was privately owned at the time, and a majority of these landowners did not actively manage their timberlands (Waldrop et al. 1989). Researchers determined that management of pine-hardwood mixtures would offer a lower cost management option than pine plantation establishment and possibly entice more landowners to actively manage their woodlands. In addition, active management of these lands would create more valuable stands for timber and wildlife than existing mixed hardwood stands. The diversity of these forests could meet multiple private landowner objectives including, timber, wildlife, recreation, and aesthetics. Trials to establish and intentionally manage pine-hardwood mixtures were established on U.S. Forest Service lands in South Carolina, Tennessee, and Arkansas starting in the late 1970s throughout the 1980s (Sims et al. 1981, Abercrombie Jr. et al. 1986, Waldrop 1989). Clearcutting or shearing of merchantable and noncommercial, low-quality stands followed by prescribed burning prior to planting pine seedlings (often sites lacked a pine seed source) were tested to avoid added site preparation costs associated with mechanical and chemical site preparation treatments. A few years after these trials were established, researchers asserted that clearcutting all stems greater than four to six feet tall and broadcast burning during the correct time of year (late spring into summer) could result in stands where pines were not being outcompeted by fast-growing hardwoods. Hardwood or volunteer pine species composition and stocking in most cases were also satisfactory in these trials (Clinton et al. 1993, Sims et al. 1981, Phillips and Abercrombie, Jr. 1987, Waldrop 1987). In the years to follow, the technique was tested in the Ridge and Valley and Highland Rim physiographic provinces with varying levels of success while planting multiple pine species (shortleaf, loblolly, and Eastern white pines) (Mullins et al. 1998, Clabo and Clatterbuck 2015, Clabo and Clatterbuck 2020).

FELL-AND-BURN SITE PREPARATION TECHNIQUES AND VARIATIONS

Techniques involved with implementing fell and burn site preparation will depend on existing stand conditions, stand or tract size, and potentially labor availability/costs. The first step is to harvest or cut any existing stems on a site either through a commercial harvest or pre-commercial harvest. Most research suggests that spring felling is most effective due to the status of hardwood root system energy reserves at this time of year. For the southern Appalachians and upper Piedmont regions, Phillips and Abercrombie, Jr. (1987) suggested May to June as the optimum timing for felling, while a study from the Ridge and Valley region of Tennessee also stated that this timing was best for silvicultural clearcuts. Greater success (species composition) has been observed if all stems greater than about 4 to 6 feet tall are harvested or cut (termed a silvicultural clearcut). If a stand to be converted to pine-hardwood mixtures contains merchantable stems and nearby markets exist, a commercial harvest can be implemented. For instance, if a stand contains mixed hardwood pulpwood and chip-n-saw size classes and enough acreage (in most regions a minimum of 25-30 acres) is present to interest a logging crew, then the stand may be harvested using conventional methods (feller buncher machine or hand fell with a chainsaw and skid whole trees to a logging deck).

In general, smaller stems than pulpwood size (pulpwood dimensions in most regions range from 5-10 inches diameter at breast height (dbh), a 3- or 4-inch top diameter, and are either whole tree length or cut into sections as small as 8-9 feet long) are cut and removed or mulched by machinery when they are felled. These types of operations can create a site devoid of any standing woody stems, and are a great option (if available) to prepare the site for a site preparation burn. In some regions, loggers may work exclusively with pulpwood mills and use a portable, onsite wood grinder or chipper. Shearing along topographic contours using a bulldozer equipped with a KG blade can cut small diameter (≥1 inch) stems at ground level and the material is then chipped on-site with a portable grinder or chipper (Figure 5). With shearing, care should be taken by the bulldozer operator to minimize soil disturbance. Forestry mulchers have become more common around the Southeast over the past several years. On flatter topography and in stands with small diameter, noncommercial stems (maximum dbh 14" for more powerful mulchers), these machines would be a great option to remove all standing woody stems

and prepare the site for a site preparation burn (Figure 6). Another potential option that can be used to fell noncommercial, small woody stems on relatively level sites is drum chopping. This may be a viable option when biomass or pulpwood chipping markets and logging operations are not available in an area. This method can be used in abandoned stands with thousands of small diameter stems per acre (Clabo and Clatterbuck 2020). With drum chopping, a steel cylinder is pulled behind a bulldozer or skidder. The hollow cylinder has several steel blades around its circumference that chop vegetation pushed over by the bulldozer as it passes (Figure 7). The chopping ability of the cylinder can be improved by adding water to increase its weight. Operators must be cautious as wet site conditions can cause rutting and damage soil on the site. Drum chopping should only be conducted in relatively dry weather.

Figure 5: *Photo A: Example of a bulldozer with a KG blade that can be used to shear or cut small, noncommercial stems at ground level. Photo B shows a grinder used with the same type of operation.*

Figure 6: *Examples of a tracked, 450-horsepower forestry mulcher (photo A) and a mulched site (photo B). Note that mulch was left on site after the operation.*

A summer site preparation burn should be completed at least a month after spring felling concludes in early to mid-June (Waldrop 1995, Abercrombie, Jr, and Sims 1986). This wait period allows downed fuels to cure and better spread of flames across the site. In addition, the dried leaves associated with spring felling act as a fine fuel promoting a more homogenous burn (Waldrop 1995, Mullins et al. 1998). Burning should be conducted by the end of September while air temperatures are still warm enough to ensure an intense burn that will consume more downed, woody fuel. Weather conditions and days since rain should be carefully monitored and assessed in the planning process for a site preparation burn. On well-drained, upland sites, summer burns can often be completed in as little as two to three days after significant rain events of half an inch or more and still achieve intensity levels to consume most woody fuels while avoiding issues with fire containment and erosion caused by extensive mineral soil exposure on highly erodible soil types (Abercrombie, Jr. and Sims 1986, Swift et al. 1993). In general, long intervals since a rain event are more of an impediment to these types of burns than short intervals after a significant rain event. Ten to 15 percent fuel moisture for ten-hour time-lag fuels (0.25-1.0" diameter) should be targeted. During late spring or summer in the Southeast, relative humidity levels between 45 and 60 percent will reduce the chances of 1-hour fuels becoming too dry and decrease spotting potential. Surface wind speeds of 3 to 8 mph are sufficient to push flames across a clearcut site. Backing fires to secure the downwind side of the site followed by strip-heading, ring, or flanking fires are the most commonly used ignition techniques. Spot ignitions may be needed for sites with more dispersed fuels or intermittent mineral soil exposure. Expect greater smoke production with a broadcast site preparation burn and create a smoke management plan based on nearby sensitive areas, fuels and forecast weather conditions (Figure 8). Additional information on conducting and planning a prescribed burn as well as smoke management planning can be found in Waldrop and Goodrick (2012) and Campbell et al. (2020).

Figure 7: *Photo A: Example of a drum chopper being pulled by a D6 bulldozer to prepare an eight-year-old, abandoned clearcut for a site preparation burn to establish a shortleaf pine-hardwood mixture in the Highland Rim physiographic region. Drum chopping was completed during March and April during dry conditions. Photo B shows a drum chopper being pulled by a skidder during dry, summer conditions in the Upper Coastal Plain region. This stand had been abandoned for 18 years and markets were not available in the region for small, noncommercial stems. Photo C illustrates a recently drum-chopped stand.*

Variations in fell-and-burn site preparation with regards to felling timing of the prior stand and burning have been attempted. A study conducted in the Piedmont region near Clemson, South Carolina on poor to moderate quality sites (site index for shortleaf pine ranged from 55-66 ft) tested winter felling versus traditional spring felling with July burning for each felling timing. This study found less fuel consumption attributed to patchier burns and fewer dried leaves (fine fuel source) on felled hardwood stems with winter felling compared to spring felling, but after six growing seasons each method produced similar stands in terms of ratios of planted loblolly pine to naturally regenerated hardwoods. Naturally regenerated oaks comprised 22-23 percent of regenerating stems with each timing (Waldrop 1997). In addition, loblolly pine had reached a dominant crown position in both treatments after six years. The authors cautioned that traditional spring felling should be adhered to on better quality sites to limit hardwood resprouts and volunteer Virginia pine seedlings during the first year after pines are planted (Waldrop 1997). A study by Clabo and Clatterbuck (2020) conducted in the Highland Rim region of Tennessee used early spring felling and fall (November) burning. Bareroot, 1-0 stock shortleaf pine was planted in this study the following April. After three growing seasons, shortleaf pine survival averaged 49%, but these sites did have problems with invasive woody species such as Callery pear and Chinese privet, which are capable of vigorous sprouting and quickly competing with planted pine seedlings. Seedlings that survived through the third growing season were not overtopped by invasive or desirable woody vegetation (Clabo and Clatterbuck 2020). Another fell-and-burn study conducted in the Ridge and Valley region of Tennessee used spring felling (May and June) but burned during September prior to planting loblolly and Eastern white pine seedlings. After 22-years, fell-and-burn plots had 30% basal area in planted pines averaged across both planted pine species and 70% basal area of natural hardwood and Virginia pine (Figure 9). Potential overstory hardwood species including oaks, hickories and yellow-poplar comprised 34% of total stand basal area. Variations in fell and burn site preparation are possible while still successfully establishing stands that meet the definition of a pine-hardwood mixture. This gives landowners and managers some flexibility in case contractors cannot adhere to narrow timelines associated with traditional fell and burn protocols.

Figure 8: *High fuel loads created by drum chopping (as seen in photo) or mulching can create more smoke with a site preparation burn (e.g. large, smoldering fuels such as logging slash) compared to a typical understory burn. A smoke management plan is important for site preparation burns where cut material is mostly left on site.*

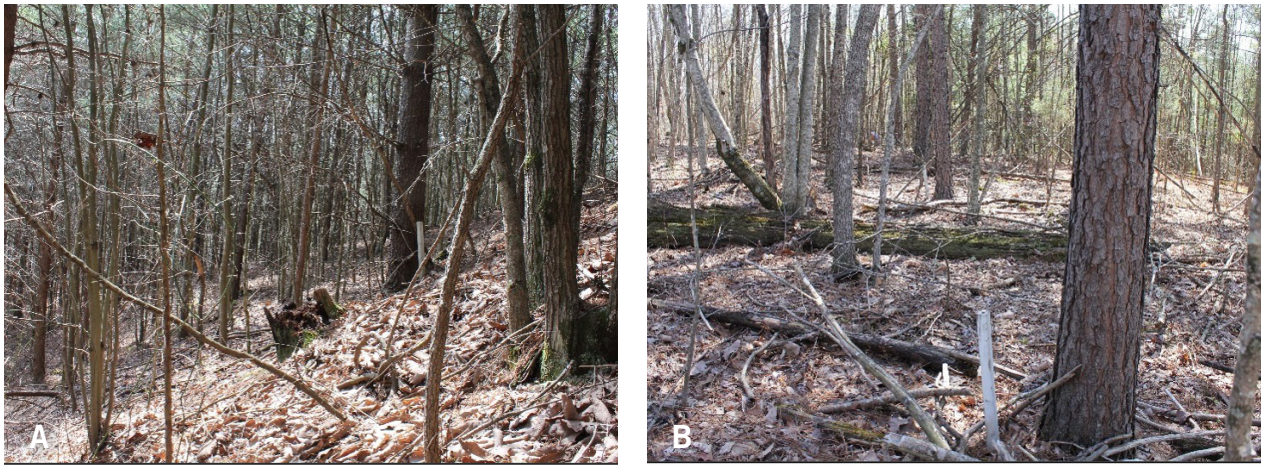

Figure 9: *Photos at age 23-years showing Eastern white pine (photo A) and loblolly pine (photo B) planted at 20x20 feet spacing as well as naturally regenerated hardwood and pine stem development after fell and burn site preparation in the Ridge and Valley physiographic province.*

SUMMARY

Fell and burn site preparation is a low-cost, low-input site preparation method to establish diverse mixed pine-hardwood forest types and improve the value of existing low quality, upland hardwood and poorly stocked pine stands common throughout the Interior Highlands of the Southeast. Landowners and managers interested in pine-hardwood mixtures should carefully assess site productivity and existing vegetation (e.g. presence of invasive plants) prior to selecting the fell and burn site preparation method to establish these mixtures. Traditional fell and burn site preparation usually consists of spring felling of all stems greater than four to six feet tall, and summer burning one month or longer after felling concludes but before the end of summer. More recent studies have shown the timing of felling and burning can be more flexible. Landowners interested in pine-hardwood management should work with a professional forester to assist them during the stand conversion and establishment processes.

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