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Restoring Fire to Long-Unburned Pine-Dominated Stands on Georgia Private Lands

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INTRODUCTION

Prescribed fire is a beneficial land management tool utilized across Georgia by trained and/or experienced forest managers and landowners to manage both agricultural and forest lands. Many Georgia non-industrial private forest (NIPF) landowners are interested in the ecological and economic benefits of using prescribed fire in existing pine-dominated stands, yet they may feel uncertain how best to safely introduce prescribed fire to stands that have been long-unburned. Long-unburned stands have either grown entirely in the absence of wildland fire (wildfire or prescribed fire) or have not burned in approximately ten or more years with hazardous accumulated fuel and understory vegetation levels dependent on site productivity and climate. Long-unburned stands have the potential for extreme fire behavior in dry conditions as compared to stands with regular prescribed fire use (Fig. 1). As well, long-unburned stands often contain a thick forest floor duff layer throughout the stand that accumulates around the base of trees and greater amounts of dead woody fuels than frequently burned stands. Prescribed fire restoration must be carefully executed to avoid damaging tree roots that grow in the duff layer of long-unburned stands, potentially leading to tree mortality. Fortunately, there are recommendations forest landowners can follow, along with prescribed fire training and assistance, to safely restore fire to long-unburned pine stands.

This publication provides an overview of how fire behaves in forest stands and discusses techniques for preparing for and implementing prescribed burns in long-unburned stands. This publication is intended for landowners who own or manage natural or artificially regenerated pine stands who may have multiple management objectives where burning could be incorporated into management to meet those objectives, including managing for wildlife habitat, fuel reduction, aesthetics, etc.

Figure 1: ***Stand conditions in long-unburned pine stands (images a and b) compared to a stand burned every 3-4 years (image c) and every year (images d) in Georgia.*** Photos by Holly Campbell

BACKGROUND

Benefits of Prescribed Fire

Prescribed fire is a wildland fire originating from a planned ignition in accordance with applicable laws, policies, and regulations to meet specific objectives.

Prescribed fire is an invaluable forest management tool that is widely utilized across Georgia. According to National Prescribed Fire Use Survey Reports (for years 2012, 2015 and 2018), on average, Georgia public and private land managers collectively prescribed burned over one million acres each reported year to meet agricultural and forestry management objectives.

Prescribed fire provides several forest management and ecosystem benefits, including:

- understory vegetation management;
- wildlife habitat management;
- plant health and reproduction of over and understory plants;
- site preparation for replanting forest stands; and
- reducing the chance or severity of future wildfires (Addington et al., 2015).

Due to its benefits, more NIPF landowners have taken an interest in prescribed fire application to their forest stands. In preparation for using prescribed fire, NIPF landowners may: consult or contract with forest managers who are Certified Prescribed Burners; participate in landowner prescribed fire workshops; take part in the Georgia Forestry Commission Certified Prescribed Burner training; and/ or participate in Georgia Prescribed Fire Council events (see Appendix)). Even with increased education and training, landowners may still feel uncomfortable safely and effectively applying prescribed fire to long-unburned stands out of a concern of overstory tree mortality, smoke management, residence time, fire intensity or severity, and other factors.

Fire Behavior and Fuels

Understanding how fire behaves is one of the first steps in considering fire restoration. Fire requires three ingredients to occur: oxygen, a heat source, and fuel (Fig. 2). Oxygen is abundant in our atmosphere and a heat source originates in nature (i.e., lightning) or by humans (i.e., spark or fire from a lighter). A fuel is anything that will burn. Fuels in a forest setting may include pine straw, duff, grass, dead vegetation, pine cones, downed woody debris, and snags.

Wildland fire is influenced by three main environmental factors: weather, topography, and fuels (Fig. 2). Atmospheric and weather factors that influence fire include temperature, precipitation, relative humidity (RH), and wind. Temperature, precipitation, and RH all influence fuel moisture. This is important since drier fuels ignite more easily. Higher temperatures, a long period without rain or a minimal amount of rain, and low RH all reduce fuel moisture. Wind provides more oxygen to increase flame intensity and can transport embers considerable distances, potentially igniting new unintended fires outside of a burn unit.

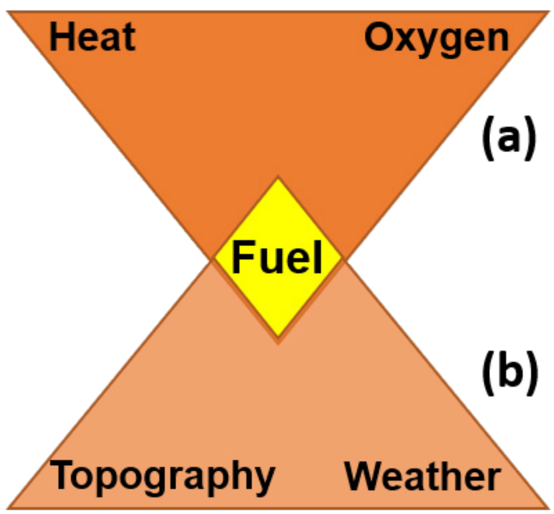

Figure 2: ***The (a) ingredients of fire (fire triangle) and the (b) fire environment triangle, with fuel shown as an important factor in fire restoration.***

Fire behavior is also influenced by topography, or slope. Fire moves faster uphill than downhill, in part, because the heat and gases from the flames downslope dry out and heat the fuels upslope, causing them to ignite more readily than if they were not pre-heated.

Lastly, fuel impacts fire behavior. As mentioned, fuel moisture influences the ignitability of certain types of fuels. When restoring fire to long-unburned stands, existing trees are protected by manipulating which fuels will burn based on approximate fuel moisture. Since fuel moisture is, in part, influenced by atmospheric and weather variables, the burner can establish a specific range of weather variables within their burn plan to meet their fire restoration objectives. This will be discussed in more detail later in the publication. There are several considerations to be aware of regarding fuels and fire restoration, including fuel size class, fuel moisture, vertical and horizontal fuel continuity, and fuel flammability.

Fuels are grouped into five main size classes or time lag categories (Table 1), based on their diameter. The concept behind fuel moisture time lags is that the characteristics of the fuel will buffer drying and wetting rates such that the lag represents how quickly fuel moisture changes in response to weather. Moisture content of 1-hour fuels and, to a lesser extent, 10-hour fuels tend to mirror temperature, precipitation, and RH changes throughout the day, whereas larger fuel classes (100 to 10,000-hr) react more slowly to these changes. For example, if your burn objectives are to only burn 1-hour fuels and not burn larger fuels, the burn would be best conducted when other fuels in a stand are sufficiently moist and unlikely to ignite. This may occur hours to days following precipitation. Though fuel moisture can be gauged by simply touching the fuel with your hand and evaluating the moisture level, fuel moisture can also be evaluated in the field using fuel moisture sticks or a duff moisture meter. It should be noted that even though forest floor duff is not included in the fuel size class table it can behave like 1,000 to 10,000-hr fuels when dry and so must be sufficiently moist when restoring fire to a stand.

TABLE 1: FUEL SIZE CLASSES

Fuel Class Size	Fuel Diameter	Responses to Changes in Temperature/ Relative humidity/ Precipitation	Examples
1-hour	< ¼ inch	Quickly	Grass, pine needles
10-hr	¼ -1 in	Quickly to moderately	Small branches
100-hr	1-3 in	Moderately	Medium branches/ sapling trees
1,000-hr	3-8 in	Moderately to slowly	Large branches/ small trees
10,000-hr	8+ in	Slowly	Stems/ trunks (on ground)

All fuels will ignite under certain atmospheric conditions (i.e., drought), but some fuels, even under moist conditions, are naturally more flammable than others due to chemical compounds in various plant parts, the shape of their leaves, moisture content, plant form, leaf litter, and more (Etlinger and Beall, 2004; Hermansen-Baez et al., 2011; Varner et al., 2015; Doran et al., 2019). For example, inkberry or gallberry (*Ilex glabra*), mountain laurel (*Kalmia latifolia*) and yaupon (*Ilex vomitoria*) were found to be more flammable than beautyberry (*Callicarpa americana*), oakleaf hydrangea (*Hydrangea quercifolia*) and rosebay rhododendron (*Rhododendron maximum*) because the former released more heat and ignited more quickly compared to the latter three species (Hermansen-Baez et al., 2011). The flammability differences in these species may be due to leaf shape, moisture content and chemical compounds. Longleaf pine (*Pinus palustris*), loblolly pine (*Pinus taeda*), and southern red oak (*Quercus falcata*) were found to have more flammable needle/leaf litter than eastern white pine (*Pinus strobus*), Virginia pine (*Pinus virginiana*), and live oak (*Quercus virginiana*) (Varner et al., 2015). Saw palmetto (*Serenoa repens*) is another southeastern plant with high flammability. Plant flammability is an important consideration in long-unburned stands. On the one hand, the landowner or land manager wishing to restore fire to a stand must consider the flammability of existing plants in the stand to avoid potential, extreme fire behavior (i.e., dense patches of highly flammable saw palmetto and inkberry). On the other hand, the stand must contain plants with sufficiently flammable litter (i.e., longleaf pine) to effectively carry fire across the stand (Varner et al., 2015).

Fuel horizontal and vertical arrangement (Fig. 3), or continuity, will determine how easily a fire can move across a stand (in combination with fuel moisture and wind). For example, continuous fuels enable a fire to spread more uniformly from one area of a stand to another whereas a more patchy burn is likely with fewer continuous fuels. Ladder fuels enable the fire to "climb" from ground fuels to shrub and tree canopy fuels (Fig. 3). In drought conditions, restoring fire to a long-unburned stand that contains a dense over and mid-story could result in hazardous fire behavior due to ladder fuels.

Reviewing fire behavior assists landowners in understanding how fire may behave in a long-unburned stand under certain weather conditions. Fuel moisture, fuel size class and weather are the most important factors to monitor or manipulate in long-unburned stands.

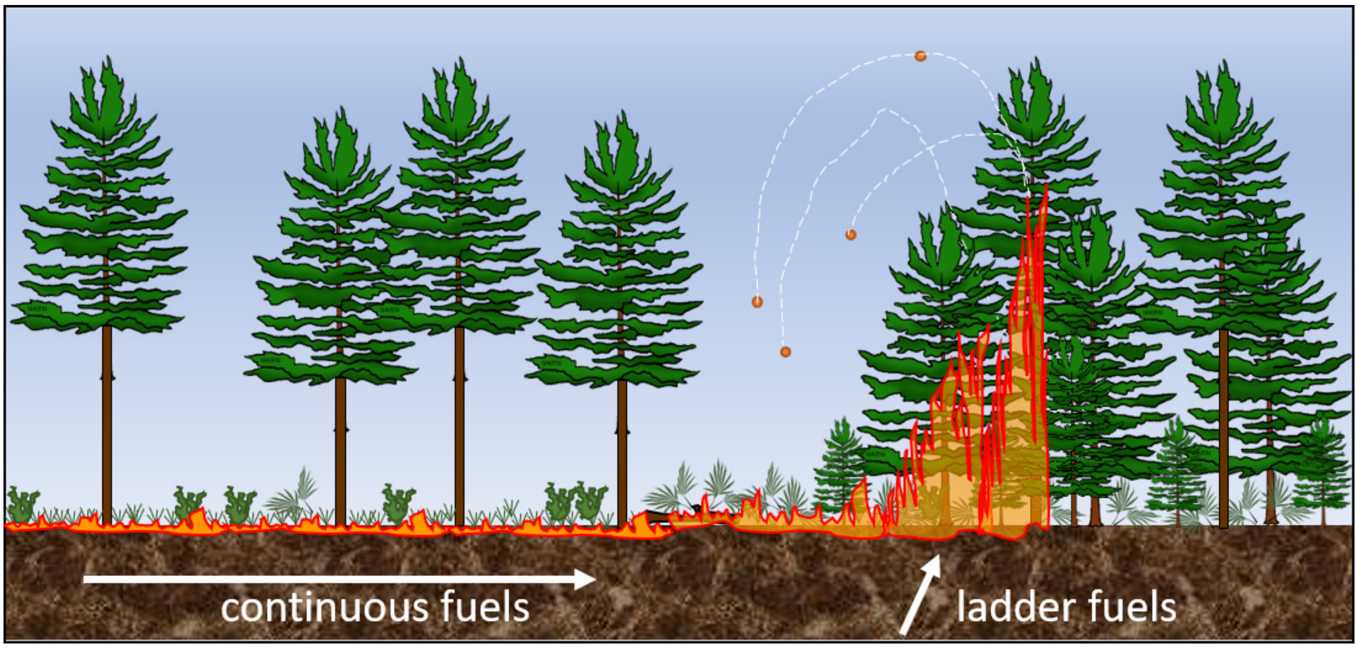

Figure 3: ***This graphic illustrates continuous (left) and ladder fuels (right) in a frequently burned pine stand (left) and long-unburned stand (right). Embers are shown emerging from the canopy, which the fire reached.***

O Horizon and The Duff Layer

In a forest, the O horizon is commonly referred to as "the forest floor," litter and/or duff layer (Fig. 4). The O horizon is nutrient-rich and improves soil health and quality. It provides essential nutrients and habitat to plants and organisms and is a location where important soil functions occur. These functions include soil aggregation (related to soil pore space and water availability to plants and microorganisms), plant nutrient supply (nitrogen and phosphorus), and the location where most microbial activity occurs (which helps support nutrient cycling and decomposition of dead materials). The O horizon is composed of various natural, or organic, materials. For example, the O horizon may contain decaying leaves, branches, roots, bark, moss, lichens, feces, and organisms, as well as living roots and organisms. The O horizon is thin in some areas of a forest and thick in others. This variation in depth is dependent on several factors, including where the organic matter originates, temperature (influences decomposition), the amount of moisture (also influences decomposition), the type of organic matter (varying rates of decay), fire history, and other factors. Lastly, the O horizon is composed of layers (a, e, i), representing various stages of decomposition. The Oi (fibric) layer is slightly decomposed organic matter (e.g., pine needles) and is often referred to as "litter." The Oe (hemic) layer is composed of moderately decomposed organic matter and the Oa (sapric) is composed of highly decomposed organic matter. The Oa layer occurs immediately above the mineral soil, which may be sandy in the Coastal Plains or clay-rich in the Piedmont, Ridge and Valley, Appalachian Plateau, or Blue Ridge physiographic regions. Both the Oe and Oa may be referred to as "duff." The duff layer is nutrient rich and in long-unburned stands is often deeper than the litter layer (Hood, 2010) and contains fine roots of trees and other plants, especially at the base of trees. Alternatively, frequently burned southeastern pine stands often lack a duff layer.

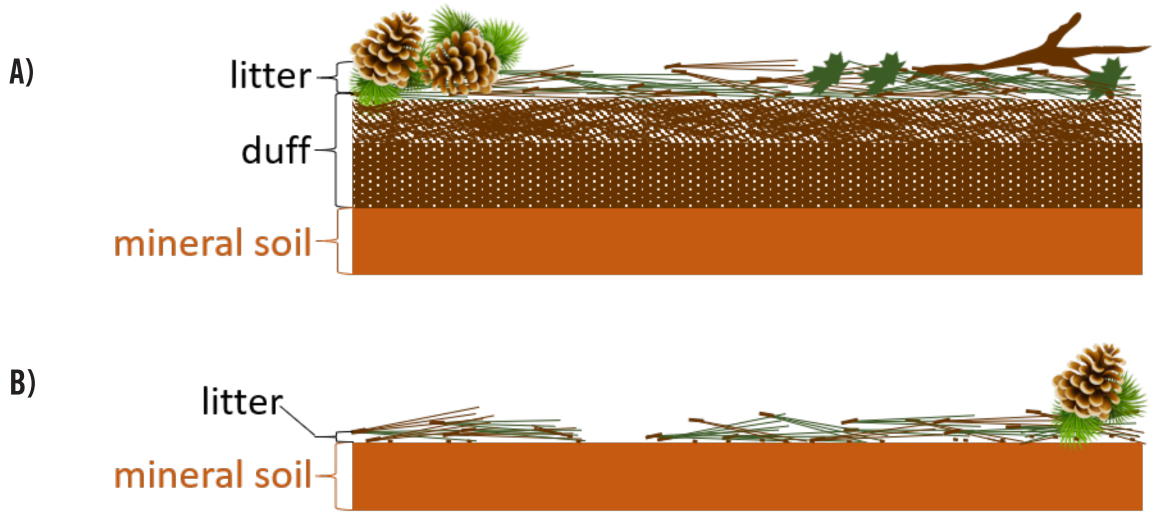

Figure 4: *Visual representation of the O horizon in (a) long-unburned and (b) frequently burned stands. Note that frequently burned stands lack a duff layer and that the duff layer in long-unburned stands can be deep depending on the duration since a previous fire. Tree roots often grow into the duff layer in long-unburned stands and can be damaged during prescribed fire restoration, if not burned carefully.*

Fire Effects on Trees

Pine species found in the Southeast have several traits that improve their tolerance of heat associated with fires. While most southern pine species are tolerant of low to moderate intensity surface fires as mature trees, differences in seedling life history are the primary drivers of fire tolerance discrepancies (Mims et al. 2018). Traits differ by species, but most southern pines have thick, insulating bark (longleaf and slash pine especially); a grass stage (longleaf and south Florida slash pine); good natural pruning (excluding Virginia and sand pines); and sprouting capability when the stem is top-killed (shortleaf and pitch pine especially). It is important to note that the fire regimes of each of these species can be adjusted to meet landowner objectives with the careful application of prescribed fire.

Fallen pine needles provide an ideal fine fuel to carry fire through a stand. Needle length affects needle arrangement and compaction on the forest floor. Longer needles tend to allow more air space among needles on the ground thus increasing the flammability of the fuel bed. Ignition is possible under a wider range of weather conditions with fuel beds composed of long needles (e.g. longleaf and slash pine). Fuel beds consisting of shorter needles pack more densely on the ground and do not allow as much air space within the needles. As a result, fine fuel flammability is lower and dryer weather conditions are typically required for combustion (e.g. shortleaf and Virginia pine) (Schwilk and Ackerly, 2001).

DIFFERENCES BETWEEN FREQUENTLY BURNED AND LONG-UNBURNED PINE DOMINANT STANDS

Conditions in Frequently Burned Stands

Frequent (every 1-3 years), low-intensity prescribed fire in natural and plantation pine stands in the Piedmont and Coastal Plains regions of Georgia create unique stand characteristics. Generally, frequently burned stands lack a duff layer (therefore, fine roots grow in the mineral soil instead of duff) and have reduced or absent midstory, in comparison to long-unburned stands. Due to the minimized midstory and more abundant sunlight, frequently burned stands also have an increased number and diversity of understory herbaceous plants that support equally abundant and diverse animal communities.

Conditions in Long-Unburned Stands

General characteristics of long-unburned stands (10+ years) include the presence of continuous and often deep O horizons, which occurs at the base of old or large pine trees and contain a dense quantity of fine roots in the duff layer. Hardwood competition is greater in long-unburned stands, and they may become the dominant midstory and overstory trees, as some shade tolerant hardwoods may live longer than most pines in the absence of disturbance. A major limiting factor of natural pine regeneration recruitment in long-unburned stands is the lack of bare mineral soil. Long-unburned stands have less understory herbaceous vegetation, due to increased shade cast by midstory trees and shrubs.

Table 2 describes general, overarching characteristics of frequently burned and long-unburned pine stands on upland sites in the southeastern U.S. This table can be used as an easy reference to the following descriptions of frequently burned and long-unburned pine stands in the Piedmont and Coastal Plains regions of Georgia.

TABLE 2: GENERAL CHARACTERISTICS DIFFERENTIATING FREQUENTLY BURNED AND LONG-UNBURNED STANDS IN THE PIEDMONT AND COASTAL PLAINS REGIONS OF GEORGIA.*

Characteristics of Frequently burned Stands
Reduced occurrence of hardwood tree competition (Brender & Cooper, 1968)
Increased pine recruitment (regeneration) (Gilliam and Platt, 1999)
Decreased midstory
Abundant, diverse, and mostly-continuous herbaceous understory (Wade et al., 2000)
Lacks duff layer (Dixon and Robertson 2018)
Tree root growth primarily in mineral soil (versus roots in duff layer)
Characteristics of Long-unburned Stands
Increased occurrence of hardwood trees in overstory (Chaiken, 1949)
Increased midstory (Gilliam and Platt, 1999, in longleaf pine stands)
Decreased herbaceous understory (Wade et al., 2000)
Increased O horizon depth (Varner et al. 2000; Wade et al., 2000), especially under older pine trees (Varner et al. 2007)
Increased fine root growth in duff layer adjacent to pine trees (O'Brien et al., 2010)
Reduced population or occurrence of fire-dependent species and plant and animal communities (Waldrop and Goodrick, 2012)

**Site characteristics may vary depending on soil type, topography, fire regime, disturbance history and other factors.*

STEPS FOR CAREFULLY RESTORING FIRE TO LONG-UNBURNED STANDS

Identify Management Objectives

It is important for landowners to define and state a list of possible objectives when considering reintroducing prescribed fire to long-unburned stands. How prescribed fire fits into short and long term stand or property objectives can help guide on the ground decisions (Table 3). Objectives should be quantifiable so that achievements can be more easily assessed and documented after a burn. For instance, in young loblolly pine stands that have reached age and size classes large enough to apply fire and not burned since stand establishment due to small tree size, an objective might be to topkill competing woody vegetation <2" diameter by at least 90% that may not have been controlled adequately through site preparation. Conversely, in mature loblolly pine stands an objective might be to prepare the seedbed for natural regeneration development prior to a final clearcut by exposing bare mineral soil across 80+% of the stand.

TABLE 3: POSSIBLE LANDOWNER OBJECTIVES FOR RESTORING FIRE TO A LONG-UNBURNED PINE STAND.

Possible Landowner Objectives
Reduce hazardous fuels in immature and mature pine stands in order to minimize wildfire risk
Suppress or control competing vegetation such as woody trees, shrubs and vines
Improve stand accessibility and visibility
Improve habitat for specific wildlife species when prescribed fire is applied to stands with low basal areas or combined with thinnings or regeneration harvests (e.g. shelterwood) that allow additional sunlight to penetrate to the understory
Restoration of fire-adapted ecosystems (e.g. longleaf pine-wiregrass, shortleaf pine-bluestem, etc.)
Expose bare mineral soil for natural regeneration from seed
Improve forage for livestock grazing

The remaining sections of this document will focus on the first two objectives in Table 3.

Identify Stand Type

Stand composition, age, and structure are major determinants for re-introducing prescribed fire to fire-excluded pine stands. The four primary southern pine species (loblolly, shortleaf, longleaf, and slash) all share similar characteristics that make mature trees more fire-resistant than associated hardwoods. Pine trees develop thick bark (this can vary considerably within the same species) and they tend to naturally prune lower limbs that could contribute to fire moving from the understory to the crown level (Keely and Zedler, 1998). Longleaf and shortleaf pine have additional characteristics that make them more fire tolerant at younger ages than loblolly or slash pine. The grass stage of longleaf pine occurs after germination and is a period of extensive root growth and limited stem growth (Stanturf et al., 2002). This stage can last several years due to competing vegetation, but prescribed fire can be used to release longleaf pine from competing vegetation resulting in rapid height growth (termed "bolting"). The terminal bud (where height growth initiates from) of longleaf pine in the grass stage is insulated from lethal temperatures by dense needles (Stanturf et al., 2002). Shortleaf pine seedlings are capable of sprouting when the stem is topkilled by fire, browsing, cutting, etc. A study conducted under uniform fuel conditions in Tennessee found that likelihood of sprouting increased as seedling age increased (age 1-3) and that seedlings reached heights by age three on moderate productivity sites where stems were able to avoid topkill (thus sprouting was not needed) after low to medium intensity burns (Clabo and Clatterbuck, 2019). This sprouting trait allows seedlings to accumulate in the understory in communities with frequent low intensity understory fires (Guldin, 2007). Low to moderate intensity prescribed fire applied under exacting weather and fuel conditions can be applied to young longleaf (by age 2) and shortleaf pine (age 3-4) stands with low seedling/ sapling mortality.

Loblolly pine is considered susceptible to fire during the seedling and sapling stages of development (Shultz, 1997). Studies have suggested that young loblolly pine (<8 ft tall) mortality following burning is most related to crown scorch, bud, and/or small branch consumption. In addition, corresponding volume growth reductions should be expected with varying levels of needle consumption (Weise et al., 1987) (Table 4). Most mortality occurs within the first full growing season following burning if insect infestations do not occur sooner (Wade and Johansen, 1987).

TABLE 4: CHANGES IN DIAMETER, HEIGHT AND VOLUME GROWTH ONE YEAR AFTER SPRING DEFOLIATION OF FOUR-YEAR-OLD LOBLOLLY PINES AT TWO SITES (ADAPTED FROM WEISE ET AL., 1987).

	Defoliation Level (%)				
Diameter Growth (in)	0	33	66	95	100
Branchville, SC	1.1	1.0	0.9	0.7	0.6
Bainbridge, GA	0.9	0.7	0.6	0.5	0.4
Height Growth (ft)					
Branchville, SC	3.9	4.2	3.1	2.2	1.6
Bainbridge, GA	3.2	2.2	2.6	2.0	1.5
Volume Growth (ft^3)					
Branchville, SC	0.14	0.12	0.09	0.06	0.05
Bainbridge, GA	0.09	0.06	0.05	0.04	0.03

Loblolly pine may require several years to develop thick bark and heights tall enough to reliably survive understory burns. Generally, once trees reach 15-25 ft tall or a minimum of 3-4 in groundline diameter then fire can be carefully reintroduced to loblolly pine stands (Schultz, 1997; Shilling and Mills, 2010) (Fig. 5).

Figure 5: ***Example of a young loblolly pine stand where fire has not been introduced yet, but trees are large enough to conduct a burn under specific weather and fuel conditions.*** Photos by David Clabo

Similar to loblolly pine, slash pine is also susceptible to mortality associated with prescribed fire at younger ages and smaller stem sizes. Illustrating this point, an observational study in Florida found that two-year-old seedlings averaging 3 ft tall had less than 1% survival following a winter wildfire with either backing or heading fires (Wright et al., 1982). In general, once trees reach age 5, 12-15 ft tall, and average bark thickness at the base of the stem reaches 0.6 in, then fire can carefully be utilized in young slash pine (Wright et al., 1982; Carey, 1992). Reports of growth reductions related to crown scorch and needle consumption have been variable with slash pine. Height growth appears to be more adversely affected than diameter growth as one study reported reduced height growth following a burn where no crown scorch was observed, while diameter growth was not affected until scorch exceeded 30% (McCulley, 1950). In young stands (age four), growth decreases the year following varying levels of defoliation (Weise et al., 1987) (Table 5).

TABLE 5: CHANGES IN DIAMETER, HEIGHT AND VOLUME GROWTH ONE YEAR AFTER SPRING DEFOLIATION OF FOUR-YEAR-OLD SLASH PINES AT TWO SITES (ADAPTED FROM WEISE ET AL., 1987).

	Defoliation Level (%)				
Diameter Growth (in)	0	33	66	95	100
Branchville, SC	0.6	0.5	0.4	0.3	0.2
Bainbridge, GA	0.6	0.5	0.4	0.3	0.3
Height Growth (ft)					
Branchville, SC	3.9	4.2	3.1	2.2	1.6
Bainbridge, GA	3.2	2.2	2.6	2.0	1.5
Volume Growth (ft^3)					
Branchville, SC	0.14	0.12	0.09	0.06	0.05
Bainbridge, GA	0.09	0.06	0.05	0.04	0.03

Vegetation structure in mature, long-unburned stands varies considerably from stands where prescribed fire is applied regularly. Shade intermediate and tolerant hardwoods often form a midstory and understory layer that can cause a wildfire hazard as pine needles drape over them. In addition, vines such as Japanese honeysuckle (*Lonicera japonica*), grapevine (*Vitis* spp.), Japanese climbing fern (*Lygodium japonicum*), trumpet creeper (*Campsis radicans*), Virginia creeper (*Parthenocissus quinquefolia*), wisteria (*Wisteria spp*.), etc. may act as ladder fuels especially along the edges of pine stands where light is more abundant for vine growth (Fig. 6). Excess hardwood, shrub, and woody vine competition also decreases pine growth rates. Pine stands where fire has been excluded also typically have low herbaceous vegetation diversity. These plants are important for wildlife browse and habitat as well as for fuels to carry maintenance burns.

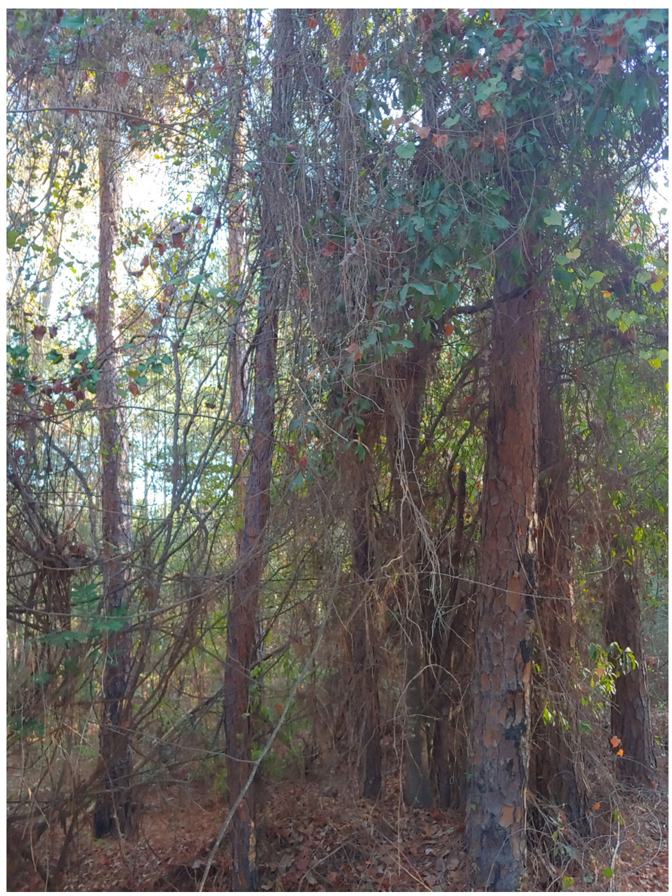

Figure 6: ***Illustration of fire excluded mixed slash and longleaf pine stand in the Coastal Plain with vines and needle drape along the edges of the stand.*** Photo by David Clabo

Throughout the Piedmont and Coastal Plain regions, pine stands can accumulate dangerous fuel loads when fire has been excluded for 5-6+ years (Wade and Lunsford, 1989). The accumulated live and dead fuels are termed “rough” and consist of dead vegetation or fuels such as pine needles, hardwood leaves, grasses, broadleaf weeds, branches (slash), logs (slash), along with live fuels. The rough in a pine stand can appear very different depending on location in the Coastal Plain or Piedmont and vary by stand age and structure. As an example, a pulpwood size class, fully stocked (e.g. average dbh=6” and at least 300 trees per acre) loblolly pine plantation in the Piedmont might have minimal live fuels in the understory due to high shade levels. Fuels in a stand like this may almost exclusively consist of pine needle litter and duff with minimal slash (Fig. 7). A very different example might be a slash pine stand grown for pulpwood in the flatwoods of the Coastal Plain. Thickets of palmetto and gallberry, which are very flammable plants, can create a thick understory of live fuels on flatwoods sites in the absence of prescribed fire or other forms of vegetation control (Fig. 8). There are pictorial guides available that can assist with determining fuel loadings, types and rough ages in the Coastal Plain and Piedmont (e.g. Scholl and Waldrop, 1999, https://www.state.sc.us/forest/fuelloads.pdf).

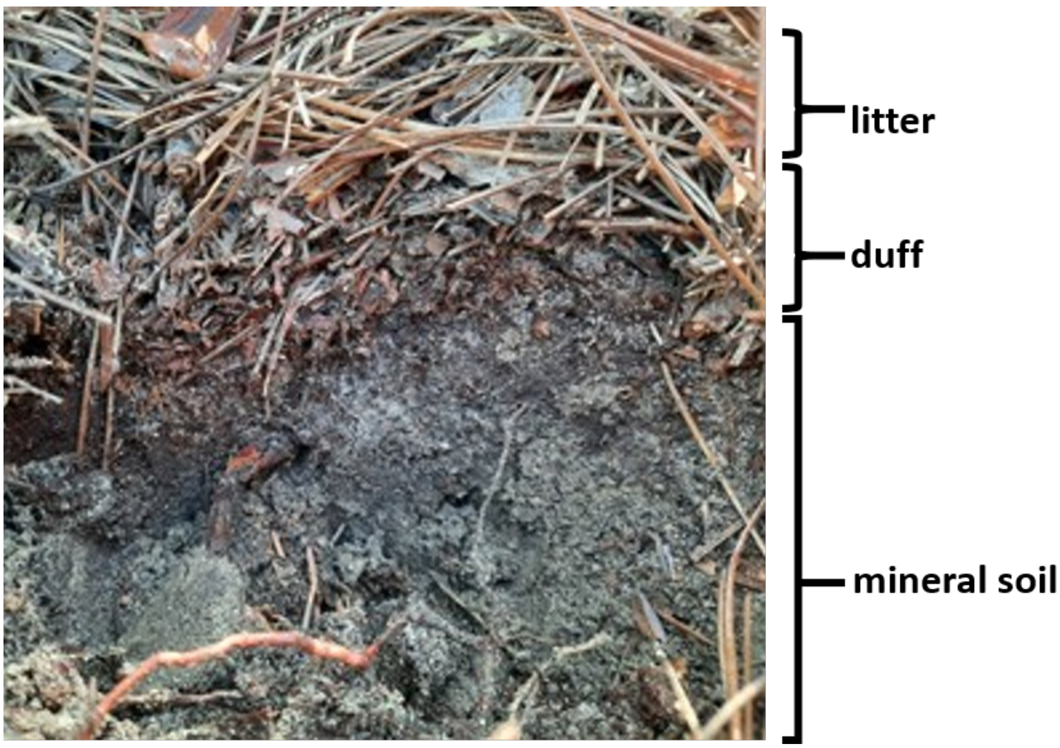

Figure 7: ***This soil profile image shows the litter and duff layers, as well as the mineral soil.*** Photo by David Clabo

Figure 8: ***This image displays a mixed slash pine-hardwood stand with saw palmetto and wax-myrtle understory in the Okefenokee National Wildlife Refuge.*** Photo by Holly Campbell

Assess Duff Layer

Other major differences between frequently burned and long-unburned pine stands is O horizon thickness and loading differences. Pine and hardwood litter can form thick layers throughout a long-unburned stand. Though duff formation rates will vary based on site characteristics, typically, duff formation begins after ten years of not burning a site (Hiers et al., 2017). One study in Alabama documented litter layer thickness in an old-growth longleaf pine stand where fire had been excluded for more than 45 years and reported litter depths of 7.6 in (Varner et al., 2000), whereas a duff layer is minimal or does not exist in stands burned every 1-3 years (Dixon and Robertson, 2018). As mentioned earlier, duff is the more decomposed part of the O horizon. Duff ignition during fire restoration is especially problematic at the base of old or large pine trees in long-unburned stands (Varner et al., 2007; Varner et al., 2016) where accumulated plant debris (i.e., bark, needles, pine cones, etc.) attracts dense fine root growth (O'Brien et al., 2010). Often, fine root growth in duff begins between ten to thirty years after fire has been excluded from a site (Hiers et al., 2017). If the duff is dry enough to burn, it can lead to fine root and even tree mortality that can sometimes be delayed one or more years after a fire (Waldrop and Goodrick, 2012). Duff burns through smoldering, which is a slow-moving, low intensity burn that moves downward and laterally, creating a heat-trapping insulating ash layer that can facilitate duff burning at high moisture contents (Frandsen, 1987; Hood, 2010). Because smoldering occurs so slowly, fine roots growing in the duff and the cambium layer of the tree stem are exposed to lethal temperatures for a prolonged amount of time and heat is transferred to the mineral soil where additional root damage can occur (Varner et al., 2009; Hood, 2010). This accumulated damage is not immediately apparent. Duff moisture is an important variable to measure and monitor prior to burning in long-unburned stands to prevent tree damage, especially since duff near the base of pine trees dries out more quickly than duff found in other parts of the stand (Varner et al., 2016). It should be noted that pine cones dry out rapidly and, alongside coarse woody debris, can ignite moist duff. Moreover, excessive duff near trees can present hazardous fuel conditions in the event of wildfire. When duff is slowly and carefully reduced through fire restoration, fine roots of pine trees will become more concentrated in the mineral soil rather than the duff layer (O'Brien et al., 2010).

Duff reduction cannot safely occur in one burn; instead, it occurs over a period of years (Dixon and Robertson, 2018), sometimes over 12 or more years in stands with thick duff layers (Hiers et al., 2017). Repeated burns should be applied every two years or less to prevent additional fuel build-up until the duff layer is sufficiently consumed. The first three burns should occur under conservative prescriptions (sufficient duff moisture and other burning conditions), while subsequent burns can be less conservative since the duff layer will have greatly reduced in depth (Hiers et al., 2017) or will no longer be present. These burns are quick, flashy fires that do not remain in one spot long enough to cause smoldering issues.

Identify Large Pines to Protect

As mentioned, large pines in long-unburned stands have thick duff layers at the base of the trees. Fine roots grow into this duff and if not carefully burned can lead to tree mortality. Prior to the burn, identify large or older pine trees you wish to protect and begin removing some fuels around the base of the tree. Rake pinecones, coarse woody debris, and the litter layer away from the tree, but take care not to remove the duff layer.

Evaluate Fuel Loading

Fuel loading refers to the amount of available fuel a fire could potentially burn per acre, usually expressed as tons/acre. Mature pine stands in the Atlantic Coastal Plain and Piedmont regions may develop dead fuel loadings of 13 tons per acre or more after 40 years without prescribed fire, whereas fuel loads can be as low as 1.5 tons per acre in annually burned stands. Similarly, live ground fuels and stems less than 1" diameter can total over 11 tons per acre after 25 years without fire while annually burned stands may only total 0.75 tons per acre (Stanturf et al., 2002). In the absence of periodic prescribed fire, fuel depths and loadings can reach dangerous levels if left unmanaged.

Determine Specific Atmospheric, Weather, and Fuel Conditions to Meet Objectives

Careful consideration of weather conditions and fuel moisture are paramount when planning any prescribed fire. It is important to plan for a range of conditions that must be met to enable burning on a given day. This ensures that the fire is conducted safely, and the chances of mishaps are reduced. If weather variable ranges are too narrow for most or all variables, then the number of suitable burn days can be extremely limited. Finding this balance is key for safely and effectively reintroducing prescribed fire to fire excluded pine stands. A summary of important weather parameters can be found in Table 6.

Temperature. Season of burning is important for reintroducing prescribed fire to fire excluded pine stands. The first reintroduction or hazard-reduction burn should be conducted during the winter months or dormant season when cooler air temperatures can limit the intensity of burns. Air temperatures below 50-60°F but above freezing are desirable for these types of burns. After this initial (or multiple) burn, season can be altered to fit stand age and objectives. For instance, to control hardwoods in young loblolly or slash pine stands, winter burns are still most optimal to reduce the risk of pine damage, whereas in older, mature stands (after at least one or more hazard reduction burns during winter) a series of summer prescribed burns are often used to suppress understory and midstory hardwoods, though other studies have indicated that burns conducted at any time of the year can be just as effective at controlling certain hardwood species (e.g. sweetgum (Liquidambar styraciflua)) (Ruswick et al. 2021).

KBDI. Several variables related to precipitation and drought need to be considered and planned for to avoid damage to the stand and the soil. Number of days since the last rainfall, rainfall amount, and a drought index known as the Keetch-Byram drought index (KBDI) are useful for determining if a stand is too dry to safely burn or too wet for good coverage. Winter hazard reduction burns are most often conducted after a cold front drops 1/2 to 1" of rain. If conditions have been dry for an extended period of time, then at least one inch of rainfall is needed to avoid possible mineral soil exposure and root damage. Preferably the rain event should be a long, soaking rain instead of a short, intense event especially on Piedmont sites with heavy clay soils. Hazard reduction fires are often performed 1-3 days after a rain event when desirable fuel moisture levels occur. The KBDI is useful for determining drought severity and potentially how dry, downed woody fuels and the duff layer will behave when burned. The index assesses soil moisture level in the first eight inches of the soil profile and is a scale of 0-800 with 0 being completely saturated (termed field capacity) and 800 totally dry (termed wilting point). For most hazard reduction burns, the KBDI should fall between 100 to about 250 (Miller and Bossuot 2000). For stands with extremely high fuel loadings and excessive duff layers, a KBDI less than 100 may be appropriate for a first burn. These conditions coincide with the rainfall amounts and days since rain guidelines for reintroducing prescribed fire to fire excluded stands. Beware interpreting KBDI following a rain that ended a dry period, as larger woody fuels may become soaked on the outside after the rain but remain dry on the interior resulting in increased smoldering combustion and smoke potential. Pay close attention to rainfall patterns during the days leading up to the scheduled burn day. On the day of the burn, it is also important to feel the lower duff layer in sunny and shady spots throughout the stand to confirm that this layer feels damp. If this layer feels dry, do not proceed with the burn. More precise measurements can be taken with soil moisture or duff moisture meters. For more information on KBDI, visit http://www.wfas.net/index.php/keetch-byram-index-moisture--drought-49.

Wind. Wind speed and steadiness are important factors for understory hazard reduction burning in long-unburned pine stands. Higher wind speeds are needed to push flames through stands that may have high densities of understory hardwoods due to fire exclusion. Understory vegetation and dead fuels within a pine stand can dramatically slow wind speeds as compared to open areas such as fields. In addition, higher wind speeds with constant direction make pine crown scorch less likely as the flaming front is less likely to stay in one spot for an extended period of time. Wind speeds at eye level should range between 3 and 10 mph and direction should be fairly constant for burning in dense stands. Winds from west to north are good for winter burns (east winds are not suitable for prescribed burning). Do not attempt to burn when there is no or minimal wind as this can result in significant pine mortality in long-unburned stands as flames and/or heat can remain over one area for longer periods. In addition, be sure that wind directions are not pushing smoke into nearby sensitive areas such major highways, airports, hospitals, etc.

Relative Humidity (RH). Relative humidity is another important weather consideration. Relative humidity is an expression of the amount of moisture in the air compared to the total amount the air is capable of holding at a specific temperature and pressure (Wade and Lunsford, 1989). Relative humidity should fall between 40 and 60+% for most reintroduction or hazard fuel reduction burns. Humidity levels greater than 60% may be needed to safely reintroduce fire to young pine plantations (Shilling and Mills, 2010). Fine fuels become dryer as RH drops, and daily RH levels are at a minimum when temperature reaches a peak in the early to mid-afternoon hours.

Atmospheric Stability and Dispersion. Atmospheric stability and dispersion variables should also be carefully considered as they affect smoke dispersion and fire behavior. Atmospheric stability conditions are often termed stable, neutral, or unstable. Stable atmospheric conditions are characterized by steady winds, poor visibility, clouds in layers and smoke near the ground, while unstable conditions are characterized by good smoke dispersion, strong gusty winds, and sunny days, yet fire behavior is usually more erratic (Wade and Lunsford, 1989). The mixing height, transport winds, and the dispersion index are important for assessing smoke dispersion potential and recognizing possible issues with fire behavior. The mixing height is the distance from the ground to a temperature inversion layer in the atmosphere. Preferred mixing heights for prescribed burning range from 1,650-6,500 feet. Transport winds represent the average wind speed and direction from the ground up to the mixing height (Waldrop and Goodrick, 2012). Transport wind speeds of 9-20 mph are most commonly used for prescribed burns. The dispersion index indicates poor or good smoke dispersion conditions. Good dispersion occurs between values of 40 and 70 and within this range is where most prescribed fires are executed.

Fuel (and Duff). Pine needles are considered a fine fuel and will be the primary fuel that carries a fire through a pine dominated stand. Fine fuel, or 1-hr (fuels <0.25 inches diameter) fuel moisture should fall in the 18-25% range (Wade and Lunsford, 1989) for hazard reduction burns. New research has suggested that pine needles may have longer lag times than other one-hour fuels (Hiers et al. 2019). An inexact but helpful test that can be done in the field to get an idea of fine fuel moisture is the needle bending test. Use recently fallen (red in color) slash or loblolly pine needles that do not have any visible signs of disease or defect. Over a ruler, bend the needle into a loop until it cracks or breaks. If the needle loop fractures or breaks between a loop width of ⅛ and ¼ of an inch, fine fuel moisture falls in the 17-28% range which includes the recommended fuel moisture range for most hazard reduction burns (Johnson, 1984). Fine fuel moisture tables that account for temperature, RH, season, time of day, and percent shade exist and can be useful for determining fine fuel moisture in the field (Appendix). The Fire Weather Intelligence Portal also provides current fuel moisture estimates from several stations throughout the state (Appendix). Remember that fine fuel moisture can change significantly throughout the day with fluctuations in RH and temperature as these variables are intricately linked (Fig. 9).

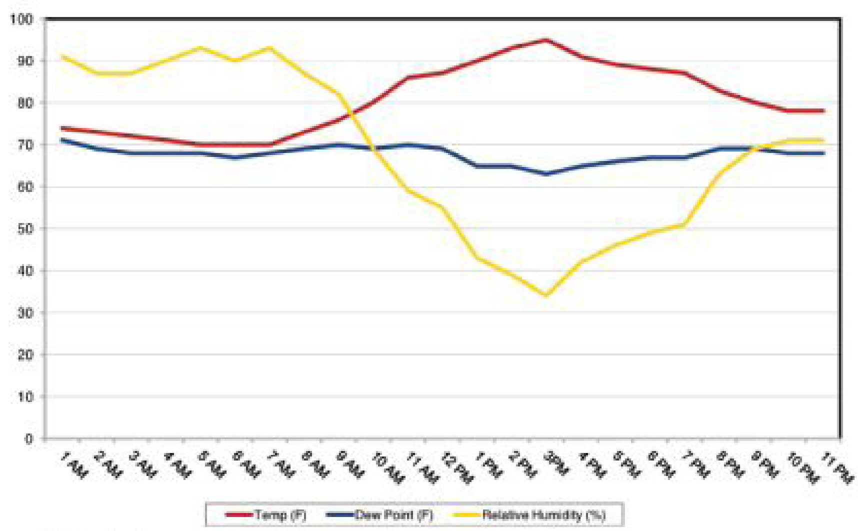

Figure 9: ***Relationship among temperature, relative humidity and dew point throughout the course of a day.*** Adapted from Waldrop and Goodrick (2012).

Burning at a specific duff moisture is recommended to avoid damaging fine roots and the lower section of the tree trunk, however much is still unknown about duff burning and thresholds to follow are very site specific. A test fire is crucial to help determine fuel moisture levels and the likelihood of a burn igniting the duff layer. The "right" moisture level will vary depending on several factors since duff depth and moisture vary greatly across a site. The prescribed burner will need to experiment with what duff moisture works best for their site, but the following recommendations may be a good place to start. Ferguson et al. (2002) suggested that burning over 86% duff moisture content limited tree mortality while Varner et al. (2007) suggested that burning with an average 85% duff moisture reduces the quantity of duff while minimizing (less than 5%) pine mortality. Other recommendations include burning over 60% duff moisture, as long as pine cones, litter, and other woody debris are removed by raking in close proximity to old or large trees of concern (Kreye et al., 2014), and Klaus (2016) recommended burning with over 80% duff moisture. Lastly, Kush et al. (2004), safely restored fire to a long-unburned longleaf pine stand by burning following a rain event and then carefully mopping up and extinguishing smoldering duff. The duff moisture levels recommended above occur several days after a large rain, after several small rains, or a week or more when cloudy days follow a large rain event (Klaus, 2016). Duff moisture can be measured by touch or with a duff moisture meter. If the duff feels moist to the touch and sticks to your hand at various depths, it may be sufficiently moist to safely burn (Dixon and Robertson, 2018). Novice burners may need input from more experienced burners to safely determine duff moisture by touch. Duff moisture can also be measured using a moisture meter (i.e., Delmhorst® BD-2100 Moisture Meter*) by raking back the litter and gently inserting the probe in the top layer of duff (Klaus, 2016). Be sure not to compress the duff when inserting the meter or a higher reading than is accurate will occur. Klaus (2016) recommends averaging duff moisture measurements across 10 or more trees, on various aspects, and on the south side of the tree, which may dry out more quickly.

*We are not endorsing this product but are simply using this as an example of one type of moisture meter.

TABLE 6: IMPORTANT WEATHER VARIABLES AND TYPICAL RANGES ASSOCIATED WITH RE-INTRODUCING PRESCRIBED FIRE TO LONG-UNBURNED OR YOUNG PINE STANDS.

Weather Variable	Commonly Used Range of Conditions
Season of Year	Winter
Air Temperature	<50-60°F
Days Since Rain	1-3 days
KBDI	100-250 (possibly <100 in stands with extremely high fuel loads)
In-Stand Wind Speeds	3-10 mph
Transport Wind Speeds	9-20 mph
Wind Direction	West to Northwest (constant direction-after cold front passage)
1-Hour Fuel Moisture	20-25%
Duff Moisture	Moist to touch at various depths or minimum 60-86% moisture (with moisture meter)
Relative Humidity	40-60+%
Mixing Height	1,650-6,500 ft
Dispersion Index	40-70

Burn Plan/ Collaborate with Experienced Burners

When reintroducing prescribed fire to long-unburned stands, a burn plan is vital to ensure a successful and safe burn. A burn plan not only helps you keep track of the tasks that need to be completed before, during, and after a burn, but it also sets the range of weather conditions that are safe to conduct the burn and it clearly delineates boundaries of the burn area. Be sure to acknowledge and address all state and local prescribed fire and smoke management laws and regulations in your plan. A burn plan will reduce the chances of accidents or mishaps for you and your crew, and a plan should be created for any burn you plan to conduct. Examples of simple burn plan templates are included in the Appendix. Novice burners can find prescribed burn assistance or advice by contacting their local Georgia Forestry Commission office, County Cooperative Extension Agent, forestry Cooperative Extension specialist, or the Georgia Prescribed Fire Council. The Georgia Forestry Commission can create firebreaks around your burn unit and be on stand-by or provide assistance while you conduct a burn, though their employees are not allowed to ignite a burn for private landowners. Some areas of the state have local Prescribed Burn Associations (PBA) where landowners can learn from one another and professionals on all aspects of prescribed fire. Landowners often collaborate to help one another conduct prescribed fires (e.g. pool equipment, manpower, etc.). Prescribed Burn Associations sometimes offer meetings and events known as "learn-and-burns", which allow for interaction among professionals and novice burners. These events are a great way for new or prospective burners to get practical, on-the-ground experience. Ask your local Georgia Forestry Commission office if there is an active PBA in your area. In addition, several other organizations and government agencies offer information on different aspects of prescribed burning and are great resources for information. A list of those organizations can be found in the Appendix.

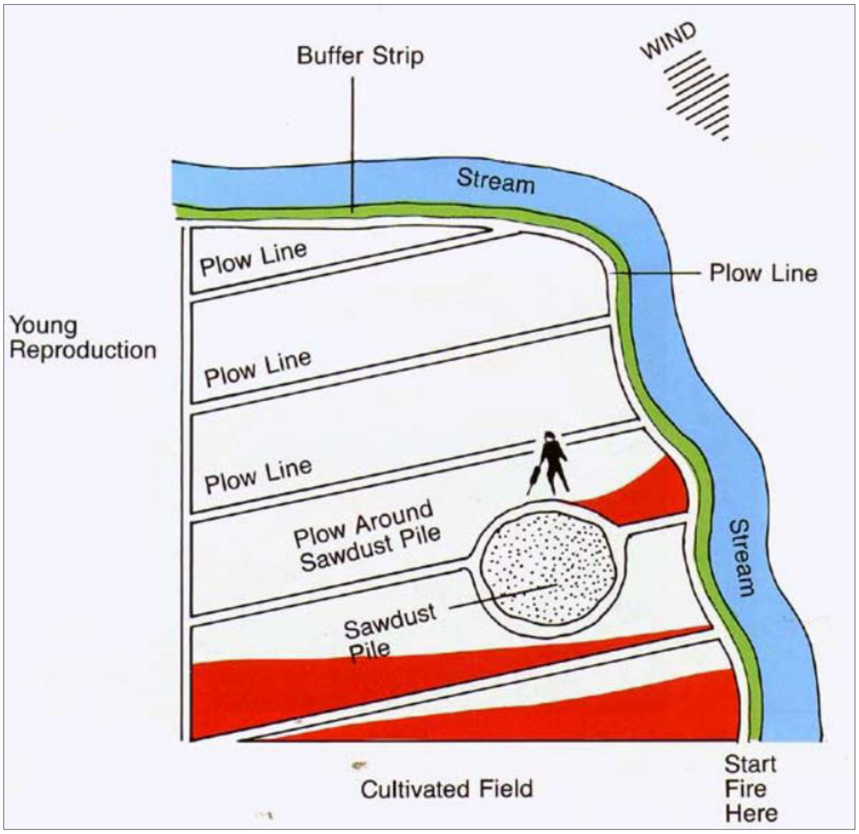

Figure 10: ***Illustration of the backing fire ignition method with the downwind starting or anchor point, interior fire breaks to decrease burning times, and exterior fire breaks*** (Wade and Lunsford, 1989).

Use a Test Fire

A test fire is important to observe how duff may be impacted before initiating a burn. Sufficient duff moisture is essential in fire restoration. **If a test fire indicates conditions may lead to excessive duff consumption or smoldering, do not burn.** Instead, select different weather and fuel (duff moisture included) conditions to burn under.

Select Firing Technique

Once a burn day is identified that meets desired weather parameters and fuel conditions, selection of a firing technique that satisfies the objectives of fire reintroduction, hardwood suppression or hazard fuel reduction is required. The firing technique chosen should match burn objectives, fuel conditions, topography, and weather forecasts to avoid damage to the stand. Backing fires are the preferred ignition technique for a first burn in young pine stands that do not yet have high fuel loads such as downed logs and large branches (especially in young stands that received good site preparation that left the stand relatively 'clean') or thick duff layers (e.g. Jackson 1974). Low flame lengths with these burns can prevent crown scorch when other weather variables are favorable. A backing fire is a line of fire that spreads into or against the wind. It is the safest and most effective method when heavy fuels are present and/or fire is being reintroduced to young pine stands after a long period of exclusion. Backing fires are ignited at the most downwind side of the burn unit from an anchor or starting point that has a fire break on the downwind side. Fire spread is slow (usually 60 to 200 feet per hour), but flame heights (a measure of fireline intensity) are usually less than 3 ft which is important to minimize crown scorch of young pine trees.

This ignition method does have some drawbacks. The slow rate of spread makes burning of larger stands in a timely manner challenging without splitting the stand into smaller burn units with mineral soil firebreaks acting as the unit divides (Fig. 9). A general rule of thumb is a fire break should be constructed at least every 1,000 feet (400-700 feet preferable) or less if all of a stand is planned to be burned using backing fires (Wade and Lunsford, 1989, Shilling and Mills 2010). If possible, fires should be ignited simultaneously from breaks spread throughout the stand in order to burn larger acreages within one day. A second drawback is wind direction and speed need to be fairly constant with this method or fire behavior and intensity may change dramatically. The third drawback is the potential for increased fine root damage if duff moisture is too low due to longer residence times and slow rates of spread with this method. Be sure to pay close attention to fine fuel and duff moisture when using backing fires as the ignition method in young pine stands.

Heading fires conducted during the winter that are pushed by relatively strong in-stand winds are the primary ignition techniques to reintroduce prescribed fire to long-unburned, mature pine stands (Fig. 9) (Outcalt 2006). These burns move quickly when good in-stand winds are present and remain in one spot a short amount of time, which is important to reduce the chances of duff smoldering occurring. As with other ignition techniques, the downwind side should be secured first with a backing fire before a heading fire is ignited. Expect more intense burn conditions and more severe effects on vegetation and soil where backing and heading fires meet. Larger stands may require strip-heading fires (heading fire usually ignited every 70 to 200 ft with the wind) to reduce fire intensity (Wade and Lunsford, 1989). Another strategy to reduce fire intensity is to ignite a series of 1 to 2 ft long strips with alternating 1 to 2 ft fire-free strips where a solid line of flames might otherwise be ignited. In many cases heading or strip-heading fires ignited under these exacting weather conditions will be patchy because of wetter fuel conditions and cool/humid weather conditions. The main benefits of this method are less smoke production, shorter flaming residence times, and the ability to use this ignition technique when fuel moisture and relative humidity are higher than with most other ignition types. The main drawbacks with this ignition technique are possible crown scorch due to greater flame heights, and uncontrollable rates of spread if weather and fuel parameters become unfavorable. Always work with a professional forester if you are unsure of your abilities, resources, etc., or lack the needed experience to conduct a prescribed burn.

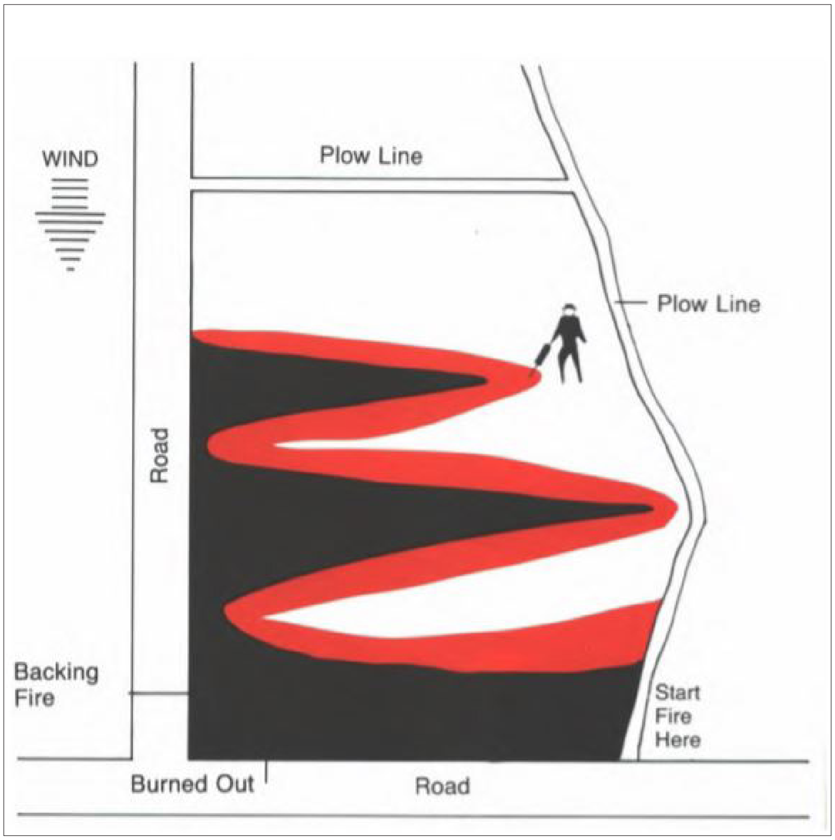

Figure 11: ***Illustration of the strip-heading ignition technique with the downwind starting or anchor point and exterior fire breaks.*** (Wade and Lunsford, 1989)

Mop Up and Individual Tree Treatments

During and especially after the burn, extinguish any smoldering duff with backpack, ATV, or tractor sprayers. Smoldering duff may not be apparent from the soil surface, so mop up is recommended over a two to three-day period (Hiers et al., 2017) around trees of concern. A leaf blower will reveal smoldering by causing remnant embers to flare up (Cammack and Pipes, 2018) and touching the soil surface enables the burner to locate additional hot spots (Dixon and Robertson, 2018). As well a FLIR ONE* infrared camera can be attached to a cell phone to see hot spots within the duff (Hiers et al., 2017).

*We are not endorsing this product but are simply using this as an example of one type of infrared camera.

Utilize Supplemental Fuel Reduction Treatments

Landowners or managers may not be comfortable with reintroducing prescribed fire to some long-unburned pine stands without attempting to reduce fuel loadings first. There could be many reasons for this uncertainty. Smoke management and proximity of sensitive areas to the stand may make finding a suitable burn day nearly impossible due to weather constraints. Personnel or fire suppression equipment may not be adequate for burning larger stands in a timely manner, or the landowner/ manager may want to lessen the chances of damaging the stand with a reintroduction burn by reducing fuel levels with mechanical or chemical methods. Additionally, the long-unburned stand may contain a high concentration of high flammability plants (i.e., saw palmetto, gallberry, etc.) that could increase prescribed fire intensity. The reasons are many for possibly combining prescribed fire with other restorative techniques, and many studies in the Piedmont and Coastal Plain have documented the utility of combined treatments.

Mowing and Mulching. Young southern pine stands (prior to crown closure) that did not receive adequate site preparation and have an abundance of small diameter woody plant competition could benefit from mowing prior to reintroduction of prescribed fire. This is especially true for pine stands on flatwoods or wet lowland sites where gallberry, palmetto, and other flammable plants occur (Huffman and Dye 1994), and on sites where mechanical site preparation such as bedding or v-blade shearing do not make the ground too uneven for a tractor to travel between planting rows. Mowing in young stands can lower fire intensity for a first burn, which should be conducted about 3 to 6 months post-mowing. Mowing can be done any time of the year, but mid-March to early May should be avoided to minimize effects on ground nesting birds that may use pine stands (Dickens and Moorhead, 2015).

Herbicide. Herbicide applications may also be beneficial for reducing live fuel loads and improving weather conditions (e.g. in-stand winds, relative humidity, etc.) for burning in young pine stands. One example of herbicide utilization in young pine stands to promote prescribed fire reintroduction is illustrated by hexazinone control of scrub oak species (e.g. turkey oak, myrtle oak, Chapman oak, etc.) in Sandhill longleaf pine ecosystems to encourage wiregrass and native herbaceous plant restoration. In these stand types, liquid hexazinone (e.g. Velpar L VU) can be applied to the soil at a rate of 2 lb active ingredient per acre on a 6 x 6 ft grid as spot applications during the spring months to successfully control scrub oaks (Brockway and Outcalt, 2000). It should be noted that this rate should be adjusted based on soil texture (see label) and rainfall is necessary within two weeks following application to activate hexazinone in the soil.
Other herbicides and application methods can be used to reduce hardwood densities in long-unburned or young pine stands. Individual stem treatments applied by hand such as basal bark, hack-n-squirt and cut stump applications may be used in stands with fewer stems per acre and/or larger stems. A major benefit of these types of treatment is they are relatively safe to the crop pine trees assuming the applicator is not careless with herbicides. A drawback is these treatments can become expensive and time consuming to execute on larger acreages. Aerial or ground broadcast applications of specific foliar or foliar and soil active herbicides may also be used to reduce hardwood densities in pine stands. For instance, certain formulations of imazapyr are frequently sprayed over-the-top of loblolly pine stands via helicopter to control mid- and overstory hardwoods during the growing season after pine growth has ceased but before leaf color change begins to occur in the fall. Understory hardwoods may be more effectively controlled using ground equipment (tractor, four-wheeler, or skidder) and predominately foliar herbicides such as glyphosate and triclopyr as long as care is taken to keep herbicide off of pine foliage. Fire behavior is likely to be more intense for a period after herbicide killed stems fall, and the effects of herbicide applications on prescribed fire behavior are dependent on time since application and dead fuel moisture at the time of burning (Wade and Outcalt, 1999).

Thinning. In mature pine stands, mechanical thinning (merchantable and pre-merchantable) may be used as a fuel reduction method in combination with prescribed fire. These treatments are often used to lower the chances of catastrophic wildfire and can be a first step for safely reintroducing prescribed fire to long-unburned pine stands (e.g. Brockway et al., 2009). Pre-merchantable thinning mostly removes woody vines, shrubs, and small hardwoods that are either too small to sell or lack nearby markets. This type of treatment is accomplished via chainsaw felling by hand, mulching machines, and traditional logging equipment. Commercial thinning or fuelwood operations remove smaller woody vegetation and vines along with hardwoods and pines that can be sold for pulpwood (e.g. Varner et al., 2000). These operations are most often performed by traditional logging crews and equipment. Mechanical thinning results in more open stands which can often influence humidity and in-stand winds thus affecting fire behavior (Waldrop et al., 2004). In addition, fine and large woody ground fuel loadings will be greater following thinning, while litter and duff layers may be reduced, especially on dryer sites (Waldrop et al., 2004). In general, the potential for more intense fire behavior increases following thinning due to the increase in woody fuels. Burning should be completed during the winter or spring within 18 month after a traditional thinning or a fuel reduction thinning treatment in order to limit excessive hardwood and vine sprouting and avoid damage to fine root systems of residual pines (Brockway et al., 2009).

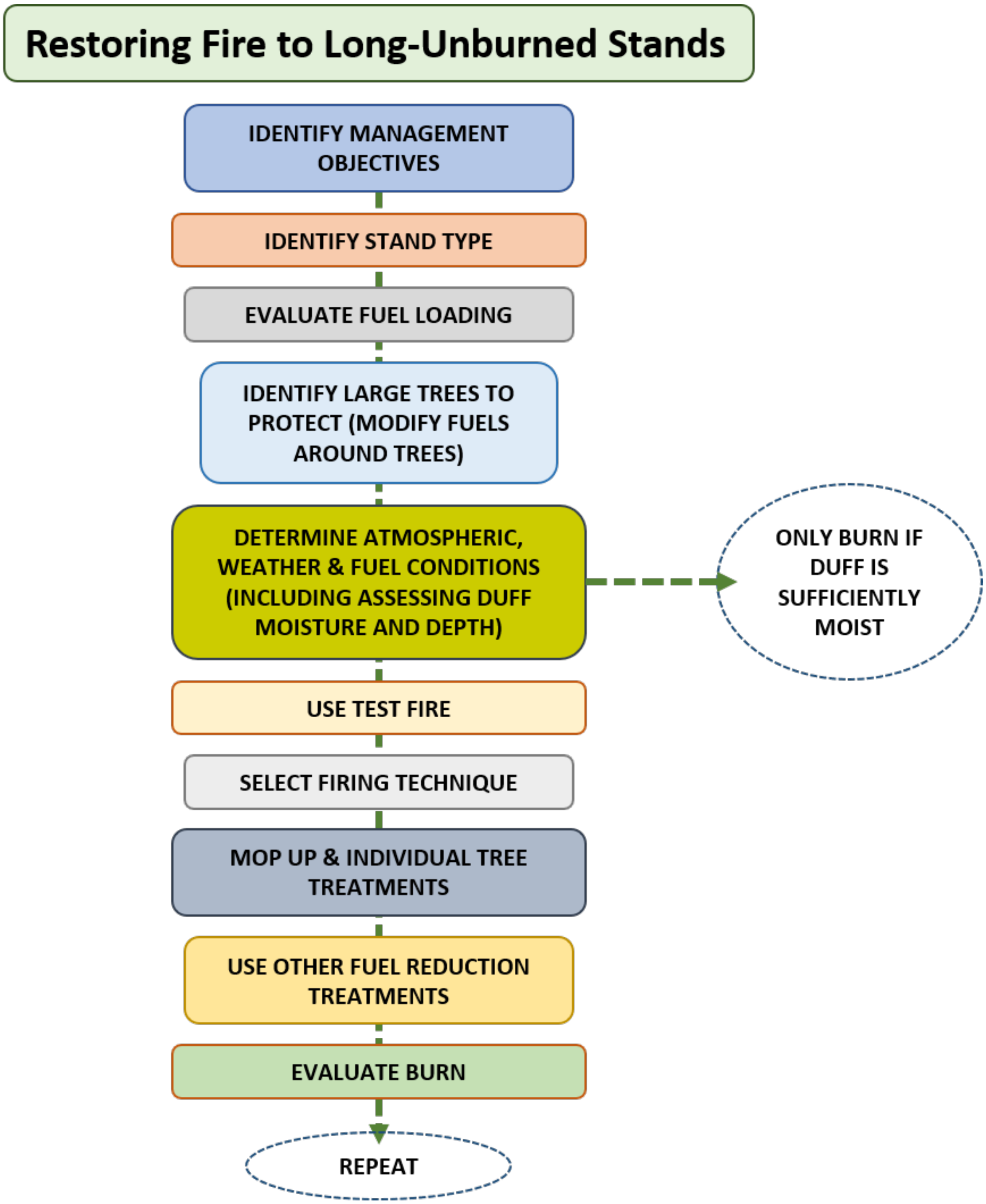

Figure 12: *General steps involved in restoring fire to long-unburned stands. Individual stands will differ in how prescribed fire can be safely reintroduced to them*

Evaluate

Document your fire restoration efforts through photographs, notes, and your burn plan for each burn. In the days or weeks following the burn, return to the site and evaluate duff reduction and other results of the burn. This can be repeated six months and a year following the burn. Record your observations for reference on future burns and as a means of evaluating the success of your fire restoration efforts.

Figure 12 summarizes the recommended main steps in restoring fire to long-unburned stands.

CONCLUSION

Prescribed fire provides several land management benefits, but introducing it into long-unburned stands can seem daunting to forest landowners. They may not know where to begin or may have concerns about fire intensity and severity, as well as smoke. Though each stand and site will differ, fire restoration to a long-unburned pine stand will be a careful and gradual process over a series of years. Some of the most important considerations in fire restoration are fuel loading and fuel moisture, especially of duff moisture adjacent to old or large pine trees. By defining management objectives; atmospheric, weather and fuel conditions; and firing technique, fire restoration can be wisely carried out alongside careful mop up, individual tree treatments, and other fuel reduction treatments.

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APPENDIX

Organizations that offer prescribed fire information to Georgia residents	
American Forest Foundation	https://www.forestfoundation.org/
Farm Service Agency (FSA)	https://www.fsa.usda.gov/programs-and-services/conservation-programs/index
Georgia Department of Natural Resources (GA DNR)	https://georgiawildlife.com/
Georgia Forestry Commission (GFC)	https://gatrees.org/fire-prevention-suppression/prescribed-burn/
Georgia Prescribed Fire Council	http://www.garxfire.com/
Natural Resources Conservation Service (NRCS) e.g. Environmental Quality Incentives Program (EQIP)	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1044009
Southern Group of State Foresters	https://www.goodfires.org/
National Wild Turkey Federation (NWTF)	https://www.nwtf.org/conservation/category/habitat
Local Prescribed Burn Associations (PBA) e.g. West Central Georgia Landowners Association	https://www.facebook.com/pg/WCGFLA/about/
Quail Forever	https://quailforever.org/Habitat/Why-Habitat.aspx
Southeast Prescribed Fire Update	https://research.cnr.ncsu.edu/blogs/southeast-fire-update/
Southern Fire Exchange	https://southernfireexchange.org/
The Longleaf Alliance	https://www.longleafalliance.org/
University of Georgia Cooperative Extension County Offices	https://extension.uga.edu/county-offices.html
UGA Warnell School of Forestry and Natural Resources	https://www.warnell.uga.edu/outreach

PRESCRIBED BURN PLAN EXAMPLE TEMPLATES

- GFC Template: http://gatrees.net/forest-management/prescribed-fire/resources/2016%20Prescribed%20Burn%20Plan.pdf
- And page 58 of the following publication: https://www.srs.fs.usda.gov/pubs/su/su_srs054.pdf

Fine Fuel Moisture Content Tables and Websites

- https://www.nwcg.gov/publications/pms437/fuel-moisture/dead-fuel-moisture-content
- https://kestrelinstruments.com/mwdownloads/download/link/id/251/
- https://climate.ncsu.edu/fwip/

The University of Georgia Warnell School of Forestry and Natural Resources offers educational programs, assistance, and materials to all people without regard to race, color, national origin, age, gender, or disability.

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