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EFFECTS OF PRESCRIBED BURNING ON TIMBER SPECIES IN THE SOUTHEASTERN COASTAL PLAIN

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Prescribed fire is a powerful silvicultural tool for controlling composition of vegetation in many of the pine timber types of the Southeastern Coastal Plain. The basic principle involved in this use, at least in this region, is that preferred pine species on their upland sites are fire-dependent at given times in their life cycles and, in effect, are subclimax on the succession scale. On the other hand, many if not most of their competitors are not fire-dependent.

In considering the effect of fire on a particular species, we must look at the direct effect on the tree at different ages or sizes. We also should examine the indirect effect as it creates either beneficial or detrimental conditions for growth or regeneration. Time does not permit our going into very much detail about these indirect effects. My discussion is limited to upland pine sites because, on the basis of present knowledge, prescribed burning does not seem to have a place as a practice in bottomland hardwood sites of the Southeast.

The term "prescribed burning" is often given to fires that clean up the logging residue and nonmerchantable trees remaining after a harvest cut. Because these fires generally are of high intensity and are not intended to be selective in their control of species, I have chosen to exclude them from my talk. I will restrict my discussion to those burns prescribed for timber stands after their regeneration and before their harvest cutting.

In the literature I reviewed for this talk I detected a subtle change in the philosophy of writers before 1941, when the term "prescribed burning" was introduced by Ray Conarro (11), and of those writing subsequently. Perhaps I have read something into the various writings which was not intended. But it seems to me that the catastrophic fires that occurred early in this century in the Lake States and West led many foresters and other concerned people into thinking that:

> Fires kill. Forest fires kill trees, destroy homes, and take human lives. Therefore, all fires are evil and destructive and they must be prevented at all costs.

Thus, the campaign was on to exclude all fires from all our forests.

But then there were also keenly observant people--botanists, foresters, and others like Mrs. Ellen Call Long, Miss Andrews (1), Max Rothkugel (39), Roland Harper (24), Herbert Stoddard (44), W. W. Ashe (2, 3), and H. H. Chapman (9)--who noted that many fires in the longleaf and loblolly pine types did not cause much damage and that different species were affected differently. In fact, Mrs. Long proposed as early as 1888 that perhaps longleaf pine required fire in its life cycle--a ridiculous idea to many. The editor of Journal of Forestry in 1913 (25), in reviewing Harper's (24) monograph on Alabama's forests, suggested that revival of that theory was an interesting psychological study! Nevertheless, the prescribed use of fire under specified fuel and weather conditions began to be practiced as our knowledge on effects of fire on vegetation began to accumulate.

When we talk about effects of fire we must put the vegetative association into an ecological perspective. Wells (51) pointed out that the Coastal Plain is a remarkable mosaic of plant communities, both successional and climax. Succession would simplify this mosaic were it not for fire, but simplification is probably neither possible nor desirable. Robert Mutch (36) has recently proposed: Many plant species may have not only selected survival mechanisms that are fire-dependent but also inherent inflammable properties that contribute to the perpetuation of these fire-dependent plant communities. He proposes an hypothesis: "Fire-dependent plant communities burn more readily than non-fire-dependent communities because natural selection has favored development of characteristics that make them more flammable".

Many of you are familiar with the characteristic inflammability of longleaf-bluestem types in Mississippi, Louisiana, and east Texas and of longleaf pine-slash pine-wiregrass-sawpalmetto types of southeast Georgia and Florida. This inflammability is true also of the loblolly-shortleaf pine types, of the pond pine types in the Carolinas and Virginia, and of the pitch-shortleaf types in New Jersey. In fact, those recommending prescribed burning in loblolly pine-hardwood types (30, 42) have recognized that to get a prescribed fire to carry and burn cleanly there must be a fairly uniform pine overstory to provide sufficient fuel for a fire to burn. Or, said another way, if hardwoods dominate a loblolly pine-hardwood stand it is difficult and at times impossible to burn except under very droughty and dry conditions. These observations seem to support Mutch's hypothesis. Flammability of fuel is probably also one of the main reasons why prescribed burning as a practice in the southeast is limited to pine types.

This leads us to another question: If pines are more resistant to fire than their hardwood associates, why is this so? Fire kills vegetation by raising temperatures in the living tissue to a lethal level, generally assumed to be about 140° F. (6). Fire may partially or completely kill various parts of a tree--its leaves, buds, branches, roots, or stem cambium (22). Thus, damage can vary, depending on the tissues that are killed. In addition to these direct effects, there may be physiological effects manifested as loss in growth.

Species differ in their reaction to fire because of inherent differences in structure; e.g., bark of different species may vary in both thickness and insulating efficiency. Hare (23) found that, with bark thickness constant, longleaf and slash pines withstood up to twice as much heat as sweetgum, cherry, and holly. He divided the species he tested into five groups in descending order of the fire resistance:

1. Longleaf, slash
2. Loblolly, baldcypress
3. Magnolia, sweetbay
4. Red maple, water oak, dogwood, tupelo gum, river birch
5. Sweetgum, cherry, holly.

EFFECTS OF FIRE ON SOUTHERN PINES

Let us look specifically at the effects of fire on pine. The size of a tree is a factor greatly influencing the damage that a fire of given intensity will do; however, it is by no means the only factor. Other characteristics of the various species are also very important.

Effects in Seedling Stage

Longleaf pine seedlings in their cotyledon stage and during their first year of growth, and to a lesser extent during their second year, can be killed by even a light fire. But, after the second year and while the seedling is still in the "grass" stage, longleaf is highly resistant. Once it starts height growth and when it is between 1 foot and 3 feet tall, however, longleaf is again more vulnerable and may be killed by fire (10, 35).

A high percentage of loblolly and slash pine seedlings are killed by light fire when they are less than 5 feet tall (3, 12). It is considered inadvisable to burn in loblolly and slash stands until they are at least 10 to 12 feet tall (12, 20). Although prescribed burns have been made with only 8 percent mortality in 4-year-old slash plantations that averaged 6 feet in height, such burns are risky (34).

We must distinguish between typical slash pine of north Florida and Georgia and the much more fire-resistant South Florida variety. In a 2-year-old study, an accidental fire burned in plots planted with both varieties. It was found that 23 percent of the South Florida slash survived in the headfires and 56 percent survived in backfires, but less than 1 percent of the typical variety survived either fire. South Florida slash pine sprouts from dormant buds along the stem and at or near the root collar, especially if the terminal bud has been fire-killed (26). Species that sprout from base of stem can have their tops killed by a fire, and yet the plant may not be completely killed. This is a characteristic of many fire-resistant species.

Longleaf has this capacity to sprout (45). The large buds with their bud-scales and sheaf of needles also provide a high degree of protection to longleaf from all but the most intense fires (6).

Shortleaf and pitch pine seedlings, although easily topkilled by fire, also sprout from dormant buds (45). In a New Jersey study (28), 70 percent of the shade-grown seedlings of both these species sprouted after a prescribed burn if they were vigorous, had well-developed basal crooks, or were more than 3/16 inch in diameter at the root collar. Sprouts from seedlings of shortleaf and pitch pines are fully as desirable as seedlings in both growth and form (28, 37). Bole sprouts are also quite common for both species. In contrast, Virginia and loblolly pines do not sprout from the bole and are much more susceptible to injury or mortality by crown scorch (28, 37). Pond pine seedlings react much like shortleaf and pitch pine in that they sprout prolifically after a light fire. Older pond pine also sprout from the bole and, because of this characteristic, will survive wet-season but not dry-season fires (52).

Prescribed fire indirectly benefits longleaf pine in its grass stage. Siggers (40) first presented data on the damaging effects of brown spot needle blight in retarding height growth of longleaf pine. He later showed (41) that prescribed burning at age 3 and at three-season intervals, or until height growth begins, was beneficial in reducing brown spot infection. Wakeley and Muntz (50) demonstrated the practicability of using prescribed fire in longleaf plantations and the resulting superiority in height.

The effects of fire on pine seedlings up to 5 feet in height may be summarized as follows:

1. Loblolly and the typical variety of slash pines are usually killed outright.

2. Shortleaf, pond, and pitch pines are topkilled, but may sprout from dormant buds.

3. South Florida slash can withstand a light fire and will also sprout at base from dormant buds.

4. Longleaf seedlings, the most fire-resistant of the southern pines, are usually not topkilled; prescribed fire is beneficial by destroying the brown spot needle blight fungus.

Effects on Saplings and Larger Sizes

The more dramatic effects of fire on saplings and larger pines are char or bleeding of the bark, needle scorch and needle consumption. An increasing amount of any of these represents increasing severity of damage. In fact, needle scorch after a prescribed burn is good evidence that either poor burning techniques were used or weather and fuel conditions were not favorable (29). Ordinarily there should be no crown scorch if all precautions are followed in a prescribed burn. The amount of crown scorch or bark char is related to tree size; i. e., the larger the tree the less the crown scorch and the lower the mortality (14).

How does a fire kill a tree but consume only a small portion of the tree? Does it kill the cambium of the main stem, or is the kill the result of bud damage and needle scorch or consumption? Cooper and Altobellis (13), in an exploratory study with loblolly pine, protected boles of one-third of the trees with asbestos wrap to 6 feet, protected another third with asbestos sheets at base of crown, and left a third unprotected. The authors found that crown damage was apparently more responsible than bole damage for tree kill. Mann and Gunter (33) reached similar conclusions by estimating needle scorch and cambium kill at ground line in a study of 11 areas burned by wildfires in Louisiana. They found that mortality was more closely related to needle scorch than to the extent of cambium kill at ground surface. Ferguson (14) gathered data on wildfires in east Texas which showed that relative crown scorch was as good an indicator of subsequent mortality as was basal damage, but the latter tended to be more subjective.

Summer burns usually have been found more lethal than winter burns (14). Although physiological factors may also be involved, this lethality seems to be related to ambient air temperatures (46). Initial vegetation temperature, which is regulated by air temperature, controls whether a given fire will raise the vegetation temperature to its lethal level (7). Summer burns are usually not recommended as first burns in heavy litter (29).

If a tree survives after its needles are scorched or consumed by a fire, growth loss inevitably follows. Such growth loss is highly correlated with the amount of defoliation (32). Because scorch and needle consumption are related to tree size, more growth loss is usually sustained by smaller trees. A single fire that caused heavy defoliation in longleaf resulted, over about 3 years, in height-growth loss equivalent to 1 year's growth (49). Repeated burns which defoliate would cause additional growth loss.

McCulley's (32) results in a slash pine winter burning study showed after 3 years that height growth was slightly more sensitive to needle scorch than was diameter growth. For example, 3-inch trees with needle scorch of 30 percent or less suffered no diameter-growth loss but had between 15 and 25 percent height-growth loss; a 100-percent scorch of 3-inch trees resulted in a 50-percent growth loss in both diameter and height. Gruschow (21) reported on this study after 5 years and concluded that the diameter and height-growth losses of trees 12 feet and taller were related to whether a backfire or headfire was used. The headfires in litter fuels which resulted in 73 percent crown scorch showed a 20 percent height-growth loss over the unburned plots; trees on the backfire plots with only a 6 percent crown scorch showed no growth loss. Diameter-growth loss was 19 percent for headfire plots and no loss on backfire plots.

Most prescribed burning in older pine stands has shown no growth losses, even under frequent burning, provided there is little or no needle scorch. This has been the case for shortleaf (17), longleaf (49), loblolly (29, 31), and pitch pines (43).

If there are no growth losses, the next question is: Does burning indirectly benefit the overstory pine growth by reducing competition from the understory vegetation? There are conflicting answers. In the Southeastern Coastal Plain, where the growing season rainfall is usually adequate, the reduction of the hardwood understory by prescribed burning in 45-to-60-year-old loblolly pine did not significantly improve the overstory growth (27, 31). In Arkansas and Missouri, where growing season rainfall is often inadequate, increased pine growth resulted after removal of understory hardwoods by herbicides. This suggests that overstory pine would also be benefited by prescribed burning (5, 18, 38, 53).

In loblolly pine at 8 years, Trousdell[1/] showed growth response over a 6-year period that amounted to a 15-percent increase in basal area following the removal of understory hardwoods. The reasons for responses in young and not in older loblolly is not clear, but physical competition between crowns of hardwoods and pine at young ages may be one of the factors involved.

The effects of prescribed fire on saplings and larger pines may be summarized:

1. For a fire of given intensity, the larger trees will have less needle scorch than smaller ones. Prescribed burning in stands less than 12 feet in height is risky.

2. Summer burns are more lethal than winter burns. Headfires will cause more damage to pines than backfires under similar weather and fuel conditions, thus winter backfires are preferred. Also, a winter burn should precede a summer burn.

3. Crown scorch usually results in both diameter- and height-growth losses.

4. Controlling understory vegetation by prescribed burning is not detrimental to overstory pine growth and may at times result in increased pine growth, especially if soil moisture is critical and provided there is no crown scorch.

[1/] Trousdell, K. B. A study of the effect of understory hardwoods on the growth of loblolly pine. Office Rep., Southeast. Forest Exp. Sta., Charleston, S. C. 1966.

EFFECTS OF PRESCRIBED BURNING ON HARDWOODS

As I mentioned earlier, one of the primary reasons for using prescribed fire in upland pines is to favor the pine over understory hardwoods. How are we able to do this? First, the bark of most southern pines has inherently greater heat resistance than hardwood bark. Second, pines have a tendency to outgrow hardwoods on upland sites and can be burned and not damaged while the hardwoods are still small enough to be topkilled. Damage to hardwoods by fire is also highly correlated with tree size, i.e., the larger the tree the less the damage by a fire of given intensity (4, 16). In prescribed burning for hardwood control the objective must be to use fire under such weather and fuel conditions that it will do little or no damage to the pine. The thrust of most work in prescribed burning in the South has been toward finding the type of fire and conditions which will do the least damage to pine and the most damage to the understory hardwoods.

Let's look at some effects of the type (headfire vs. backfire), season, and frequency of burns (annual, biennial, and periodic) on understory hardwood vegetation.

Topkill of Hardwoods

Headfires, because of their greater intensity, generally will topkill more stems of all species than will backfires; summer fires, because of higher air temperatures, also topkill more stems than winter fires; small stems are more easily topkilled than larger stems (4, 15, 30). Stems smaller than 1½ inches usually suffer 80-100 percent topkill in a single winter fire; the topkill drops to between 10-30 percent for 4-inch sizes. Sweetgum is consistently more susceptible than oaks in all diameter classes (4, 15, 16). Sweetgum and oaks also tend to show a difference in topkill between seasons, with summer burns having the highest rate, but the topkill of oaks may be more variable and in some cases not significant (15). Except for a few stems which may be completely killed, most hardwoods will sprout at the base after a winter fire (15).

Complete Kill of Hardwood

Periodic winter prescribed burns--although they topkill hardwoods in diameter classes up to about 4 inches--completely kill only a relatively small number of rootstocks (3, 16, 29). Neither do single summer burns completely kill large numbers of hardwood stems. In studies in South Carolina (30) and Arkansas (19), a single summer burn killed less than 10 percent of bayberry, blackgum, sweetgum, and a mixture of oaks; in east Texas the complete kill of oaks from a single summer burn was similar, but the complete kill of sweetgum was about 40 percent.

Now the question arises: What about effects of repeated annual burns, both summer and winter? In a South Carolina study, four annual summer burns eliminated 50 percent more small hardwood stems and 66 percent more shrubs than did four annual winter burns (8). In another study in South Carolina, 100 percent of bayberry, and 65 percent of the blackgum were completely killed after seven annual summer burns. Two biennial summer burns killed about half as many of the same species as four annual burns when these frequencies were compared (30). In a similar comparison in south Arkansas, Grano (19) found that biennial summer fires were effective in killing rootstocks of oaks but not of gums or other species. Presumably, repeated summer burning, when food reserves in the root are lowest, gradually reduce vigor and kill the plant (8, 42).

How long lasting is the effect of a prescribed burn or burns on hardwoods? Evidence indicates that hardwood vegetation recovers to its previous state from a single summer or winter burn in 5 to 7 years. In a Virginia coastal plain study, the recovery of hardwood and shrubby vegetation was measured 2, 4, and 6 years after a winter burn was followed by either one, two, or three annual summer burns, all of which preceded a harvest cut of loblolly pine. The shrubby vegetation recovered after 4 years (47), but differences in hardwood vegetation were still apparent after 6 years (48). What seemed to have happened was that pine reproduction captured the space formerly occupied by the hardwoods because total mass of vegetation produced was about equal after 6 years (48).

CONCLUSIONS

I have reviewed the effects of prescribed burning on timber species growing in the pine types of the Southeastern Coastal Plain.

Prescribed burning, if used properly, can effectively influence the amount and size of the hardwood component in pine stands. Prescribed burning also has a place in controlling brown spot needle blight on longleaf pine in its seedling stage. Little damage or loss in growth results from a prescribed burn in pine if needle scorch does not occur. Except for longleaf pine and to a lesser extent shortleaf and pitch pines, the earliest a prescribed burn can be used without a great deal of risk or damage is after the stand is 12 or more feet tall or about 8 years of age (less on better sites). In pine stands where hardwoods are a problem, winter prescribed burns at 5-to-8-year intervals will usually keep the hardwoods small during the rotation. Just prior to harvesting the stand, a series of two or three annual summer burns will further reduce the vigor, size, and amount of hardwood component, thereby preparing the area for the next rotation.

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