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PRESCRIBED BURNING IN SELECTION STANDS OF SOUTHERN PINE: CURRENT PRACTICE AND FUTURE PROMISE

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ABSTRACT

The selection silvicultural system as practiced in stands of the major southcm pines is briefly reviewed and tbc past and present role of prescribed burning in each is discussed. A detailed diissiou is given of the burning practices in uneven-aged stands of longleaf pine (*Pinus palustris*) in which repeated fire is both highly effective and nearly essential as a management tool. A promising scheme to adapt cyclical burning to the management of other less fire-adapted pine species under selection management is discussed along with a sketch of research and pilot testing needed to bring such a scheme into practice.

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INTRODUCTION

Uneven-aged management. or practice of the selection silvicultural system in southern pines, tends to be a localized activity. It is not currently the prevalent nor best understood system over most of the South. Operationally, on industry and private lands, it has been most common in the past in the pineries west of the Missiisippi River and currently is a method employed in some form by a number of consulting foresters across the South. The pulp and paper industry *is the de facto* role model for forestry in the South and their methods employ even-aged systems, which are often very simplified, over very large areas. These methods serve the aims of this industry very well but they tend to produce a low-value primary product which is not the best product for all timber growers, especially the small nonindustrial private (NIP) forest owner. Profits from pulp and paper come from added-value secondary and tertiary manufactured products (e.g., pulp, paper, containers, chemicals) and not from the raw or primary product itself (e.g., pulpwood, wood chips). But, the NIP producer must make his profit from stumpage or sale of a primary product. Therefore, it is in their best interest to market as valuable a product as possible (such as sawlogs, veneer bolts, utility Roles) while keepiig out-of-pocket costs as low as possible. The selection system favors large, high-value products and is well-adapted to continuous production of timber on rather small areas. Hence, it Should be of considerable interest to NIP owners and the consulting foresters who advise them.

To best portray the status of prescribed burning in Selection stands of southern pine, it is first necessary to discuss the features of the selection system as applied to the different species. Therefore, a brief description of selection silvicultural practices will first be given, followed by associated specific uses of fire, and a discussion of information needs.

SILVICULTURAL PRACTICE

History

Uneven-aged management in southern pines dates from the mid-1930% when R. R Reynolds of the Southern Forest Experiment Station, U.S. Forest Service, initiated research on the selection system in natural loblolly-shortleaf *pine* (*Pinus taeda, P. echinata*) stands in southeastern Arkansas (Reynolds 1959). This line of research has continued until today and large areas of industry, state, and private land were managed in the western Gulf area of the southern United States by the method. Many of these locally-owned industrial properties were later purchased by forest industries from the U.S. West Coast who subsequently instituted even-aged management, but considerable area is still managed in the western Gulf area under a selection silvicultural system. Brender (1973) also conducted uneven-aged management research in loblolly pine in the southern Georgia Piedmont for mote than 20 years. Loblolly-shortleaf holdings encompassing a few hamdred to several thousand acres each are known to be currently managed under a form of uneven-aged management in Alabama, Georgia, and Florida. There are undoubtedly others unknown to the author.

Research similar to Reynolds' was started for longleaf pine (*P. palustris*) by the Southern Station in the late 1940% in south Alabama, abandoned after about 15 years, and resumed in the late 1970's (Farrar and Boyer 1991). This work includes operational cyclical prescribed burning. At least one lumber company owning some 250,000 acres (101,171 hectares) of longleaf pine in south Alabama reportedly managed its stands under 'an uneven-aged system up to the

1960's, when the land changed ownership and management. Several private longleaf tracts in south Georgia are known to be currently managed under a form of uneven-aged management. However, the majority of remaining longleaf stands are now managed under an even-aged system, especially those in public ownership.

Loblolly and Shortleaf Pines

Both loblolly and shortleaf are amenable to uneven-aged management under a single-tree selection silvicultural system. The prevalent regulation procedure in operational management of uneven-aged loblolly-shortleaf stands is the "volume/guiding-diameter at breast height-limit" (V/GDL) technique of Reynolds (1959, 1969, et al. 1984, Farrar 1984, 1996) or a variant thereof. The procedure essentially provides regulation of yield by volume control in the sawtimber component and is facilitated by use of a guiding-dbh-limit. In this procedure an observed stand-and-stock table from an inventory is presupposed and the steps are as follows: (1) a target future sawtimber volume per acre is chosen; (2) the expected compound sawtimber growth rate is determined; (3) a cutting cycle length is adopted; and (4) a residual volume is proposed that will grow at the expected rate to produce the target volume at the end of the cutting cycle.

The proposed sawtimber volume that is left may be, or approximate, that which will achieve the fully stocked working optimum suggested by Reynolds (Farrar 1984) at the end of the cutting cycle, if site quality and stand conditions permit. If not, it may be set lower initially with the aim of gradually approaching full stocking by cutting less than growth over several cutting cycles. The proposed cut is the difference between the observed sawtimber volume and the proposed leave volume. If it is operable, it is removed. If the proposed cut is not operable but very nearly so, another slightly lower but reasonable future volume may be adopted, slightly increasing the proposed cut to an operable level. Otherwise, the cut is deferred until sufficient volume is available. At the end of the cutting cycle, a new future volume is chosen which may be the same or larger than the first, depending upon whether or not full stocking has been achieved.

The working optimum volume at. the end of the cutting cycle suggested by Reynolds was developed principally for production of high-quality sawlogs on productive southeastern Arkansas sites. It is necessarily scaled lower on poorer quality sites. The guiding-dbh-limit is used to designate the sizes of trees to be cut aud is determined by accumulating the allowable cut volume by starting with the largest dbh class in the observed stock table and moving down through the dbh classes until the allowable cut volume is accumulated. The dbh class in which the cut is accumulated is the guiding-dbh-limit. If such a cut were made it would be a simple diameter-limit cut, but this is not done in practice; hence the term "guiding." In practice, some poor trees below the limit are marked and some good ones above the limit are left while marking

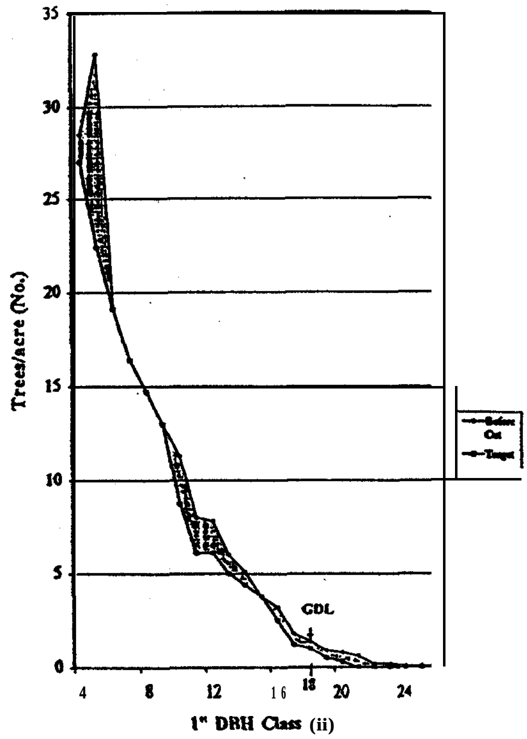

Fig. 1. Observed stand table showing a volume-g.d.l. (Guiding Diameter Limit) cut (shaded).

a volume equal to the allowable cut. The marking rules are simple: "Cut the worst and leave the best." Poorly-formed, diseased, slow-growing. and badly-positioned trees are cut, and the best-formed healthy, fast-growing. and well-positioned trees are left. Note that the sub-sawtimber volume component is not formally regulated in this method but manipulated according to the experience of the practictioner. A graphic illustration of a V/GDL cut is shown in Figure 1.

A second, and more objective procedure for regulating stands under a selection system has been developed by research and has been applied in a number of operational stands of several southern pine species. It is the "basal area/maximum dbh/q" (BDq) technique of regulating the merchantable growing stock by leaving a theoretically prescribed, balanced, uneven-aged, target structure specified by chosen BDq criteria (Brender 1973; Trimble and Smith 1976, Marquis 1978, Farrar 1981, 1984, 1996). It has been used in loblolly-shortleaf (Farrar and Murphy 1989, Farrar et al. 1989), loblolly (Murphy and Shelton 1994), and shortleaf (Murphy et al. 1991). Essentially, in construction of a BDq target, the chosen residual basal area (B) per acre is distributed over the dbh classes between a maximum dbh class (D) and a minimum merchantable dbh class by the adopted q (constant ratio of the number of trees in succeeding dbh classes in a balanced uneven-aged stand). See Marquis (1978) or Farrar (1996) for details on constructing a BDq target structure.

The items in a BDq structure are listed in their order of importance. The B or basal area is the most important because it is the residual growing stock or growth base and it should always be left as specified.

The D or maximum **dbh** is next in importance and is largely a financial maturity and/or risk consideration. It is generally the largest tree **size** returning an **ac-ceptable** rate of growth, and/or the risk of losing it **without** salvage is acceptable. After the B criterium has been met, the D criterium is met if possible but **trees larger** than the D may be left if **necessary** to meet the B critetium. The q is third in importance and is necessary to specify the target residual structure. However, necessary adjustments to the residual target **struc-ture** to cancel deficits often result in the specified q **being** altered and becoming nonconstant in the final **leave** structure. The specified q may be retained where Possible in the *find* leave structure and is used to **dis-tribute** the compensating basal area required to cover deficits but it may **necessarily** be variable in the final **structure.** Thus, after the B and D criteria are met. the **prescribed** q is imposed as closely as is feasible.

Again, regulation via **BDq** is fundamentally by **volume** control but in practice the stand table is manipulated to leave a target number of **trees** and basal area per dbh class and per **acre** rather than a stand volume ***per*** se. The entire merchantable growing stock is potentially regulated. not just the **sawtimber.** As before, an observed stand-and-stock table from an inventory is presupposed. A target residual stand structure per acre (stand table) is constructed according to reasonably chosen **BDq** and cutting cycle criteria. The **BDq** residual structure and cutting cycle are chosen together so that the residual structure will grow at an **acceptable** rate during the cutting cycle. This will **pro-**vi& a terminal structure that can be again cut operationally to leave the target structure or as close an approximation to the target structure as possible.

The target residual stand table is compared to the observed stand table by dbh classes and the observed excess is tentatively available for cut. Note that this Process specifies rather precisely the number of trees to be removed in each dbh class. If there are no deficits in the observed stand table and the tentative cut is operable, the tentative cut is the allowable cut. **However,** if there are deficits (some observed dbh classes **contain** fewer trees and less basal area than corresponding target dbh classes), the residual target stand table is adjusted so that the required total merchantable **basal** area **per** acre is left. This is ideally done by leaving additional basal area in lower dbh classes with **sur-**Plus trees to match the missing basal area in deficit classes. **If** this is not Possible, the **required** basal **area** to **cover** the deficits is left, as required, **in dbh** classes **above** the deficit classes. The adjusted residual stand **table is then compared to the observed, and the excess, if operable.** is the **allowable** cut. If it is not **operable but very nearly so, a somewhat lower B and/or D may be chosen** (but this is not **generally** recommended), and the whole process of **determining the residual tar-**get structure and allowable cut is **repeated.** Usually, if **the cut is** not operable, it is deferred until the observed stand table becomes adequate. Again, the marking **rules** are simple: "Cut the worst and leave the **best,"** and in **practice** some additional Poor trees may he cut **below** the D if they are compensated for by leaving

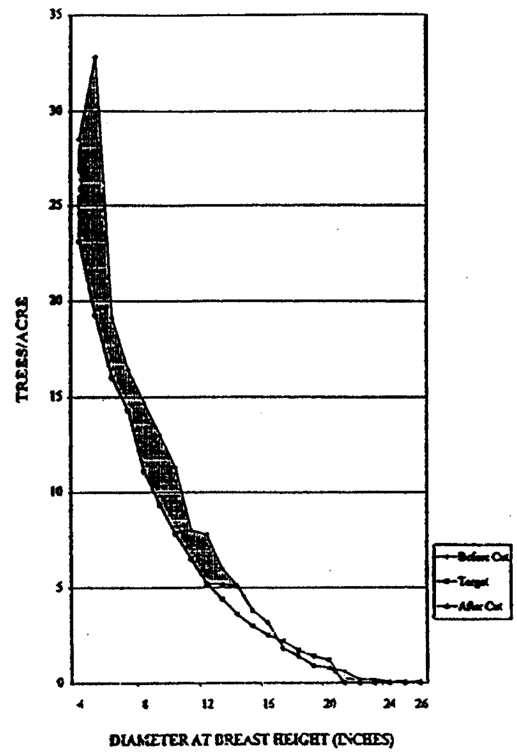

Fig. 2. Adjusted residual Basal Area-Diameter-q stand table and adjusted cut (shaded).

an equivalent **basal** area in good trees above the **D.** A **graphic illustration** of a **BDq** cut is shown in **Figure 2.**

Target **BDq** criteria for western Gulf area loblolly-shortleaf stands have been devised by using observations on the change in B, D, and q over time, using Reynolds* optimum final structure and volume targets **as** models, **and generating BDq** structures that re-map Reynolds' information. Generally, for a S-year cutting cycle, a residual structure of B = **60** square feet Per **acre** (13.8 square meters Per hectare), D = 18 to 20 inches (45.7 to 50.8 centimeters), and a 1 inch q = 1.15 to 1.20 would be expected to produce volumes and **basal** areas that would grow to closely approximate **Reynolds'** final working optima. The B and q of this structure appear to have wide **application and have** been extended as first-approximation working **criteria** to stands of Pure loblolly, **shortleaf,** and **longleaf** pines. The D criteria and cutting cycle are **tailored** to fit the growth capacity of the usually Poorer **and,** sometimes, better sites.

Longleaf Pine

Longleaf pine **is** also amenable to **uneven-aged management (Farrar** and **Boyer** 1991, **Farrar** 1993, 19%) but, due to Poor seedling **growth in response** to **competition from** mature **adjacent** or **overstory** trees, **single-tree selection** is not **recommended. Instead, a** modified groupselection system is **recommended** in which allowable cutting is used primarily to **release reproduction,** as needed, **from** such **competition** and to establish any needed reproduction before a group is removed. Groups of mature **trees** are not removed until adequate regeneration is established beneath them.

This system includes cyclical prescribed burning as an integral component (discussed later). Both the V/GDL and BDq regulation techniques discussed above for loblolly-shortleaf have been applied to operational longleaf stands in south Alabama (1970's) and in south Georgia and north Florida (1990's). The major departure in BDq application has been to lengthen the cutting cycle to 10 years or longer to ensure an operable allowable cut on the poorer sites now generally occupied by longleaf pine. For the same reason, the major departures for V/GDL have been to lower the terminal target volume and lengthen the cutting cycle.

The group-selection system for longleaf pine, including burning, holds promise as a forest management technique which will readily permit continual commercial timber production in a given stand that is compatible with conservation measures required for the endangered red-cockaded woodpecker ***(Picoides borealis).*** Redcockaded woodpeckers (RCW) are sedentary. Such a system should continuously provide suitable nesting and foraging habitat within the same stand so that the bird should never have to abandon a stand due to habitat deficiencies and search out a new and more suitable one. The maximum dbh requirements in the BDq structure are set relatively high to insure adequate production of suitable nest trees and relaxed to insure that all nest trees are retained without regard to size while still meeting the specified residual basal area target. As in any burning program with RCW, the nest trees will require fire protection. Since a forest cover is continuously maintained and soil disturbance is minimal, group-selection in longleaf pine may also be suitable for compatible timber management and maintenance of other endangered or threatened, but fire-adapted, animal species such as the gopher tortoise ***(Gopherus polyphemus).*** Such a group-selection system with prescribed burning has been recently imposed as an operational test on a 700-acre (283 hectare) longleaf pine tract containing RCW on the Apalachicola National Forest near Bristol, FL.

Other Species

Examples of uneven-aged management in species of southern pine other than loblolly, longleaf, and shortleaf pines, in either a research or operational context, are unknown to the author. A single-tree selection system similar to that used in loblolly-shortleaf pine should have application in stands of slash pine ***(P. elliottii)*** and it is very likely that some schedule of prescribed burning could be effectively adapted to selection management of this species. This will be discussed later. The West Florida or Choctawhatchee race of sand pine ***(P. clausa var. choctawhatchee),*** due to its high tolerance of competition and production of at least a component of nonserotinous cones, should be an excellent candidate for management under a form of single-tree selection. Burning probably cannot be used on an operational basis due to the species' reputed low tolerance of fire at all stages. Herbicides will thus be required if periodic hardwood control is needed. Because sand pine is so competitive and grows so rapidly, control of other vegetation is not as important as it is with other pine species. The Ocala race of sand pine ***(P. clausa var. ocala),*** due to its serotinous cones, is not suited to single-tree selection. However, it might be suited to group selection or even-aged patch-clearcutting where natural regeneration is obtained from cones in logging slash opened by reflected solar heat. Spruce pine ***(P. glabra)*** is also a very tolerant pine and is found in association with bottomland hardwoods principally on the natural levees and ridges of major stream bottoms in the eastern Gulf Coastal Plain. It would appear to be well suited to single-tree seleetion if the area it occupies and its value warrants separate management from the bottomland hardwoods. Otherwise, it can probably be maintained as a mixed-stand component under the management applied for the hardwoods. Prescribed burning is likely to have little or no use in selection management of sand pine or spruce pine.

PRESCRIBED BURNING

Loblolly and Shortleaf Pines

Undesirable, low-value hardwoods will eventually dominate southern pine sites unless natural succession is interrupted or reversed. Prior to settlement this was accomplished mostly by fire. but windstorms and other natural catastrophes. alone. and in conjunction with fire, can also reverse succession and prolong pine dominance. However, these natural agents cannot. be expected to be timely and effective in typical forest management contexts. Further. prescribed burning has largely been avoided in selection management of loblolly-shortleaf stands and is not normally applied operationally to uneven-aged stands. The rationale is that prescribed fire repeated on a suitable schedule, during appropriate seasons, and of sufficient intensity to control unwanted hardwoods will prevent the pine regeneration necessary to sustain the system. Consequently, the unwanted hardwoods are periodically controlled principally by some combination of harvesting merchantable. stems and controlling nonmerchantable stems by girdling or herbicide application. On occasion, fire may be applied in advance of. a good seed crop to prepare a seedbed but loblolly and shortleaf do not require the essentially bare mineral soil seedbed requited by longleaf. Usually, the scarification provided by skidding equipment during cyclic cuts can be expected to provide suitable seedbed.

Nonetheless, because burning is a relatively inexpensive silvicultural tool and has many side benefits, methodology to adapt it to selection stands of southern pine, besides longleaf, needs investigation and development. Exploratory work has been started on regular (systematic) cyclic prescribed burning in selection-managed stands of loblolly-shortleaf on a 6-year cutting cycle in southeastern Arkansas but only preliminary results have been reported (Cain 1993a). Winter fires were applied at 3-, 6-. and 9-year intervals, plus no burning, starting in 1981, to stands having 40, 60, 80, or 100 square feet per acre (9.2, 13.8, 18.4, 23.0

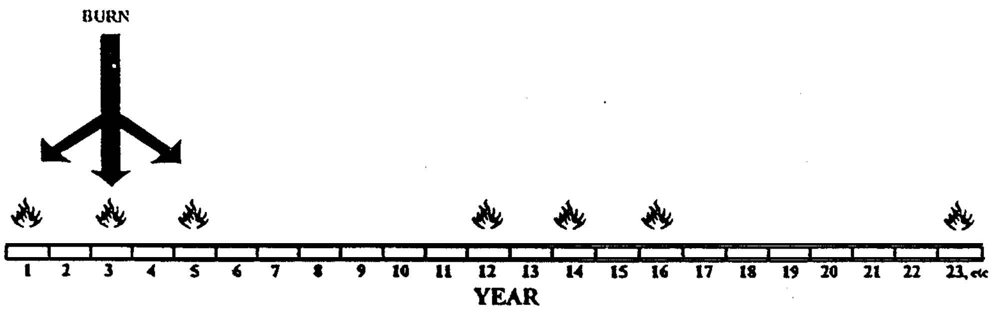

fig. 3. An example of interrupted cyclic burning.

square meters per hectare, respectively) of merchantable pine basal area. All hardwoods over l-inch (2.54-centimeters) groundline diameter were first killed in these stands by injecting herbicide. After 10 years the results indicated that density and stocking of pine regeneration were negatively correlated with s&and den-&y. Burning did result in submerchantable pine regeneration well above 200 stems per acre (494 stems per hectare) under the usual range of selection stand densities (40 to 80 square feet per acre (9.2 to 18.4 square meters per hectare)) but recurring fires reduced regeneration to levels considered marginal. The unburned plots (herbicide only) contained 2 to 6 times as much submerchantable pine as plots which received recurring fires. Recurring fires did reduce the size of hardwood stems but not the number (average = approximately 4,560 rootstocks per acre (11,268 per hectare)). Pine stand density had no effect on number or size of hardwoods.

The use of regular cyclic winter bums has not been tested for suffidient time to evaluate its use for controlling competing hardwoods while allowing establiihment and ingrowth of adequate pine reproduction to sustain the uneven-aged stand. However, a preliminary conclusion in the above report was that, rather than a rigid cyclic bum schedule, an irregular burning program might be more successful in controlling hardWoods and securing any needed pine regeneration. In such a program, annual or biennial bums would be made for an indefinite period until a good seed crop occurred. Burning would terminate before seedfall and, assuming successful reproduction establishment, not be resumed until the needed submerchantable pine component has reached a size resistant to prescribed fire. It is assumed that the amount and status of regeneration would be periodically monitored during merchantable inventories at about S-year intervals to determine the need for regeneration. Herbicides might Occasionally be required after extended no-burn periods to bring hardwoods under control. As a result of the above conclusion, the study was redesigned in 1991 to compare no burning with 3 winter bum intervals (irregular; 5-, and lo-year) and only under 60 square feet per acre (13.8 square meters per hectare) of merchantable pine basal area (the usual recommended leave density on these sites for a 5-year cut-% cycle).

In 1985, a companion exploratory demonstration to the above "basal area-bum" study was initiated in which interrupted cyclic burning was applied to a selection stand of loblolly pine and one of shortleaf pine, each managed to leave 60 square feet per acre (13.8 square meters per hectare) of merchantable pine on a 6-year cutting cycle (Cain 1993b). Interrupted cyclic burning is a schedule of bums where a stand is burned at a certain interval (e.g.* every 2 years) for a period (e.g.. 3 bums) and then not burned for a few cycles (e.g., 3 cycles or 6 years). The schedule is repeated through time. In the demonstration, all hardwoods one-inch (2.54 centimeters) and larger dbh were initially controlled with injected herbicide and then winter burns were applied every 2 years for 6 years, followed by a no-bum period of 6 years. The first burn was in 1985 and burning was repeated in 1987 and 1989. Submerchantable pine was sampled in 1990-91 and preliminary results (Cain 1994) indicate that repeat burning resulted in more than adequate pine seedlings (1.15 1 per acre (2,844 per hectare)) but insufficient saplings (15 per acre (37 per hectare)). Inventories in similar but unburned selection stands where hardwoods had been controlled by operational herbicide application indicated that this treatment was much more effective than repeat burning in promoting establishment of submerchantable pine and controlling submerchantable hardwoods. However, the interrupted bum treatment has not been evaluated for sufficient time to draw firm conclusions.

The notion remains viable that for loblolly, shortleaf, and slash pine there should be some repeated combination of a period of cyclic burns followed by a no-bum period that would adequately keep competing hardwoods under control and yet allow enough pine reproduction to become established, survive, and develop to provide the necessary ingrowth reservoir. The schedule of burn and no-bum periods, the time interval between burns, and the type and season of burn would likely differ by species and site conditions. As an example, Figure 3 illustrates a repeated schedule of 3 bums at 2-year intervals followed by 6 years without burning. To prevent excessive damage to the pine reproduction, the first burn in each burn period may need to be a winter burn but the others might be spring or winter burns depending upon the need to retain pine reproduction or control hardwoods. If the burner is highly skilled and an excellent judge of buming and fuel conditions and pine reproduction susceptibility, the first burn after a no-burn period could be conducted during spring. Further, as suggested above, the

	Fire Cycle			
Year	3 Winter	3 Spring	3 Winter/2 Spring	2-Random Occurrence
1	W	S	W	W
2				
3				
4	W	S	W	
5				W/S
6			S	
7	W	S		S
8			S	
9				S
10	W	S	S	
11				
12				
13	W	S	W	
14				W/S
15				
16	W	S	W	
17				S
18				
19	W	S	W	
20				
21			S	W/S
22	W	S		
23			S	S
24				
25	W	S	S	

Fig. 4. Selection longleaf cyclic prescribed bums.

period of burns may need to be irregular and predicated on the status of need for submerchantable pine in the stand rather than strictly adhere to some fixed schedule. Both approaches should probably be investigated for all three pine species. Based on past experience with loblolly-shortleaf pine, the rule of thumb is that a component of regeneration needs to be secured every 10 years to adequately sustain selection structures and this will probably also apply to slash pine.

Herein, winter and spring burning are defined as occurring under the following seasons and conditions. Wmter burning is done during the dormant season during the months of December, January, and February after most 'of the current season's fall of pine needles has occur& and before deciduous hardwood buds begin to break. Spring burning is done during the early growing season during the months of April, May, and early June after hardwoods have leafed out and before summer air temperatures reach summer peaks. Ideally, to obtain best control of hardwoods, spring burning is done soon after hardwoods are fully leafed out, when their root reserves of food have been depleted in this process, and before root food reserves have been replenished.

Longleaf Pine

In contrast to the selection system in loblolly-shortleaf pine; prescribed burning is both desirable and

Table 1. Target minimum frequency of submerchantable stems in selection stands of southern pine.

DBH (in.)	Class (cm.)	Number per Acre	Number per Hectare	Percent
0	0	54	133	27
1	2.54	46	114	23
2	5.08	40	99	20
3	7.62	32	79	16
4	10.16	26	69	14
		200	494	100

essential in group-selection in longleaf pine; probably more so than in even-aged systems, The fire tolerance of longleaf seedlings, saplings, and trees permits repeated burning to control undesirable vegetation and prepare seedbeds while allowing a sufficient ingrowth reservoir of seedlings and saplings to become established under sparse patches of overstory and to survive and sustain the system. Generally, burning is done in winter and is cyclic on a 3-year rotation on average sites (see program "3 W" in Figure 4). Most burning is done in winter due to the large "window" of suitable burning days where the combination of cool air temperature, steady moderate wind, suitable humidity, and adequate fuel moisture frequently occur. This prevalence of good and safe burning weather usually insures that all of the scheduled area can be covered with minimal pine damage. Once the hardwoods too large to be controlled by winter fire have been eliminated by cutting or herbicide, a 3-year cyclic winter bum schedule will often keep the competing hardwood and brush below breast height although little or none will be killed.

For about 30 years,, periodic inventories have been made of seedling and sapling densities on the pilot study areas of longleaf group-selection under 3-year winter burning on the Escambia Experimental Forest in south Alabama. These inventories have shown an increasing submerchantable pine stand that greatly exceeds the theoretical minimum number of saplings required in Table 1. This indicates no practical adverse effect of winter burning on the ingrowth reservoir. Also, these winter burns over about 30 years have largely kept the encroaching hardwoods in check although recent observations indicate that a significant and increasing component has survived the burning program. This suggests the need to resort to a temporary series of spring burns to bring the hardwoods back under control.

If hardwoods begin to escape the regular 3-year winter burning or if the sites are good and support vigorous undesirable vegetation, the cycle and season may be changed to 2-year spring burning for a period until the vegetation is reduced to a State where resumed winter burning can control it (see program "3W/2S" in Figure 4). Also; it has been shown that spring burning promotes height growth and does not decrease survival in stands of even-aged longleaf seedlings (Grelen 1978, 1983, Maple 1977) and may increase seedling. ingrowth into sapling sizes under shelterwood overstories (Boyer 1997). Perhaps these findings will also hold for uneven-aged stands where the seedling environment is much more variable and the intra-specific competition much more complicated. However, the "window" of good and safe burning conditions for spring burns is much smaller than that for winter burns. Also, intensive spring burning on short cycles to best control hardwoods may not be the most desirable program for joint and intensive management of some species of wildlife, such as bobwhite quail (*Colinus virginianus*), wild turkey (*Meleagris gallopavo*), and other ground-nesting birds. Therefore, it is suggested that spring burning in selection-managed longleaf should be used on a temporary and priority basis to bring vegetation under control, and to possibly promote seedling growth and recruitment into saplings. Winter burning should generally be the operational norm.

Exceptions will occur. For example, on very good sites it may be necessary to continually use recurring spring fires, such as the "3 S" program shown in Figure 4, to keep hardwoods in check. Also, it may be desired to imitate a natural timing and sequence of burns. The program "2–5RO" in Figure 4 illustrates burning at random intervals from 2 to 5 years apart with the first burn in any series being either a winter bum or a spring burn depending on fuei load. As shown, spring burning is used as much as possible assuming that spring is the most likely period of natural fire occurrence and that it will be needed to keep vegetation in check in such a bum pattern.

Prescribed fires in the group-selection system of longleaf pine management are designed to completely cover the area while concurrently minimizing pine damage. Ideally, they consume the upper layers of the needle and grass litter while retaining a thin and patchy component of moist decayed litter near the soil surface. Some scorch is unavoidable on saplings and smaller poletimber but it should be minimized on the larger size classes. Such fires often do not bum all parts of the selection stand equally well. Bums are often complete and hot enough to control brush in the patches of mature timber, poletimber, and saplings but may be cool enough in grassy seedling groups with little needle litter to allow some hardwood escapees until an adequate needle litter develops. The fires are usually headfires or flankfires, depending upon the fuel and weather conditions. Generally, such fires can be set earlier in the day under cool and moist conditions that preclude a backfire and will cover the area much more quickly than a backfire with less damage to seedlings. Backfire is used primarily to make firebreaks wide enough to safely contain a headfire or flankfire. To minimize damage to seedling and sapling groups, it may be desirable to set spot fires in these and let them bum out before the balance of the stand is fired, Particularly in spring burning.

The net-effect scenario of cyclical prescribed burning in selection-managed longleaf appears to be as follows: (1) the bums are repeated every 2 or 3 years; (2) hardwoods are kept in check and seedbeds are periodically prepared by the bums; (3) adequate seed crops occur irregularly at 3- to IO-year intervals and some coincide with good seedbeds; (4) many seed, seedlings, and some small saplings are lost to fire, particularly under areas of dense overstory with high needle fuel; (5) some seedlings are established and survive under areas of sparse overstory, around sparse edges of mature timber patches, and in openings; (6) the allowable cutting releases seedlings and saplings, destroys some of the regeneration, prepares areas for regeneration, if needed, and thins the balance of the stand; and (7) enough seedlings and saplings survive in this process to provide an adequate ingrowth reservoir to sustain the stand.

The recent rapid shift to growing-season bums across the Gulf and Atlantic coastal plains is viewed by the author with some reservation. Longleaf pine evolved with frequent natural surface fires, which probably occurred most frequently in the growing season. and developed a strategy to reproduce itself under these conditions on a long-term basis through a number of adaptations. This strategy does not necessarily produce the best tree growth nor the best stand production often desired by humans, especially under harsh fire regimes. Although the species is highly adapted to fire it can be badly damaged and killed by fire quite readily under some conditions such as high summer air temperatures, moderate fuel loads, and very low fuel moisture. The prudent forester interested in good timber production along with other forest uses will use fire only as intense and as often as necessary to achieve necessary understory control while minimizing damage to the pine stand. Otherwise. "The operation may be a success but the patient may have died." Therefore, in a multiple-use selection-management context favoring timber production, the author prefers: (1) using winter bums as much as possible to control understories, prepare seedbeds, and possibly minimize damage to the pine stand; (2) using spring bums only when and where needed to reduce understories to a condition that can then largely be maintained by winter burning and/or to possibly promote needed pine ingrowth; and (3) using summer burning very rarely and most judiciously, if at all.

INFORMATION NEEDS

The major need for information on burning in selection stands of southern pines is for loblolly, shortleaf, and slash pines. The cyclical burn schedules currently employed in selection longleaf (i.e., "3 W" and "3W/2S" in Figure 4) appear to be widely applicable and effective. The main need in longleaf is to pilot-test the techniques in demonstration stands at various locations. These tests should include most, if not all, of the schedules shown in Figure 4 and should certainly contrast winter versus spring burning as a minimum Research will be warranted if these pilot tests uncover problems that cannot be solved operationally. In selection stands of the other three major southern pines, we need both research and demonstrations of interrupted and irregular. cyclic burning. Research needs include investigation of combinations of season of bum, burn interval, bum period, and no-bum period

Year	Fire Cycle					
	2/5-6	2t7-6	2/7-8	2/7-10	2/Irr.	1/Irr.
	W	W	W	W	W	W
2						S
3	S	S	S	S	S	S
4						S
5	S	S	S	S	S	S
6						S
7		S	S	S	S	seed
8					seed	
9						
10						
11						
12	W					
13						
14	S	W				W ?
15					W ?	W/S ?
16	S	S	W		W/S ?	W/S ?
17					W/S ?	W/S ?
18		S	S	W	W/S ?	S
19						S
20		S	S	S	S	S
21						S
22			S	S	S	S
23	W					seed ?
24				S	S	
25	S				seed ?	

Fig. 5. Possible interrupted cyclic bum programs.

in replicated long-term studies for each species at several locations. Weather and fuel conditions; fireline intensity. and fire effects on pine reproduction (by size) should be documented by bum treatment. Further, long-term work should investigate the minimum ingrowth reservoirs (numbers and sizes of submerchantable stems) required to sustain a selection stand. Until now, without burning, we have always depended upon an excess of reproduction to sustain the system but with burning we will likely have to concern ourselves with a more meager reservoir. Such information would also be useful in longleaf selection stands.

However, the existing climate for starting and maintaining long-term research is poor and the next best thing will be to initiate some demonstrations or pilot-tests in each species at a few locations. The demonstrations should probably include the 2 or 3 programs most likely to succeed The merchantable and submerchantable portions of these test stands should be inventoried every 5 years although the cutting cycle may be longer. Vii such monitoring the necessary submerchantable ingrowth reservoirs will be converged upon by observation over time. Some interrupted cyclic bum candidates are shown in Figure 5 where the program legends 2/5–6, 2/7–6, etc., indicate the burn interval, the number of years in the bum period, and the number of years in the no-bum period. For example, 2/5–6 means burning every 2 years in a 5-year period followed by 6 years of no burning. The "W" and "S" in Figure 5 represent winter and spring burning, respectively.

The most likely candidates are 2/5–6, 2i7-6, and 217-8 year cycles. The 2/5–6 program might be suited to slash pine. The relatively frequent seed crops and fire tolerance of slash pine may allow a good stand of seedlings to become established in a 6-year no-burn period and then survive in sufficient numbers to sustain the selection stand when biennial burning is resumed for the next 5-year bum period. Both the bum and no-bum periods could be adjusted plus or minus a few years, within limits, to secure sufficient repro duction. A crop of sustaining submerchantable pines should be established every 10 to 20 years and, according to current knowledge, every 10 years would be better. The 2/7–6 and 2/7–8, and possibly the 2/7–10 programs, or some such bum and no-bum program not exceeding about 15 years, may be suitable for loblolly and shortleaf pines. The bum period might be shortened if the competing vegetation is not too vigorous, but a no-bum period of about 8 years may be required to allow loblolly pine regeneration in a selection stand to grow to a size that sufficient numbers can withstand the resumption of cyclic burning. Cain (1993a, 1994) found that loblolly saplings in selection stands need to be at least about 1" (2.54 centimeters) dbh and 8 feet (2.4 meters) tall to survive winter bums that result in crown scorch exceeding 60%. Therefore. bums need to be tailored to minimize damage in reproduction patches while performing adequately elsewhere. It may be that group-selection should be considered in selection stands of loblolly, shortleaf, or slash pines to provide larger areas of lighter fuels beneath reproduction and result in less damage. Hence, in all these possible interrupted cyclic burn programs, the first burn following a no-burn period may best be a relatively cool winter bum to reduce the fuel load and minimize damage to pine regeneration. Most of the subsequent bums should be spring bums, as shown, to maximize vegetation control before entering a no-bum period (see Figure 5).

The last two programs in Figure 5 represent irregular cyclic bum scenarios. The 2/Irr. program entails an initial winter bum followed by 2-year spring burns until a good seed crop occurs; in this example, in the fall of the 7th year. Burning ceases then and resumes about 8 to 12 years later, depending on the fire-resistant status of the reproduction, with a winter bum followed again by 2-year spring burning for 6 or so years until another crop of reproduction needs to be established. The 1/Irr. program differs only in that burns are at l-year intervals and the bum period may be a year or so shottec

In any management program for selection stands, the amount and status of submerchantable pines should be assessed periodically. Thii should be done during each merchantable stand inventory using a systematic sample of at least 100 nested milacre and 1/100-acre plots. Seedlings are tallied on the milacre and saplings are tallied on the 1/100-acre plot. Their free-to-grow status is estimated by noting whether or not they are overtopped by overstory, understory, or both. Probably, as a first-approximation to an absolute minimum, the numbers Of submerchantable trees per unit area given in Table 1 should be present at any given inventory. As a guess, at least 2/3 to 314 of these submerchantable stems should be free-to-grow (not overtopped by overstory or understory) and 100% in this condition would be best. As a safety margin and pending better information, 2 to 3 times this amount of reproduction probably would be desirable at the end of a no-bum period before burning resumes.

It is thought that among the options available, there should be some practical program(s) of interrupted or irregular cyclic burning for loblolly, shortleaf, and slash pines. But, if a bum and no-bum program no longer than about 10 to 20 years cannot reliably maintain a sufficient submerchantable pine ingrowth reservoir, then other procedures may be necessary. The most obvious one would be to protect regeneration areas from burning until the reproduction is resistant while continuing to bum for vegetation control in the rest of the stand. This would entail monitoring reproduction and seed crops and interrupting burning to secure any needed crop of seedlings in openings or low-density portions of the stand. Then firebreaks would be established and maintained around the regeneration areas and they would be protected for a number of burns until a sufficient number of their trees are fire-resistant. Probably. about 5 to 10% of the stand area would need to be in such protected patches at any given time. A group-selection system would apparently lend itself well to such a program. Unplanned examples of such a program have occurred in pine stands maintained for quail hunting in the Southeast where "ringarounds" or patches of escape cover have been protected from burning for a number of years and allowed sapling stands of pine to develop in them, which resisted subsequent burning. If all else fails, the standard remedy of herbicide application about every 10 to 20 years remains an option. Burning in selection stands of lobioliy, shortleaf, and slash would then remain an occasional event for such purposes as seedbed preparation, hazard reduction, wildlife benefits, or improving visibility for timber harvesting activities.

To obtain management information and provide demonstrations, Tail Timbers Research Station (Tallahassee, FL) has recently installed cooperative pilot studies of pine uneven-aged management and prescribed burning in south Georgia and north Florida. During 1994 six operational stands of natural longleaf pine were put under group-selection management with three of the stands to be burned every 3 years in winter and three to be burned every 3 years in spring. During 1996 four operational stands of natural loblolly-shortleaf were set up for single-tree selection management with two stands to be burned under a 2/7–8 year interrupted cyclic bum program and two to be burned under a 2/Irr. irregular cyclic bum program (Figure 5). Also, during 1996 two operational stands of natural slash pine were put under single-tree selection with one stand to be burned under a U5-6 year interrupted cyclic bum program and the other to be burned under a 2/Irr. year irregular cyclic bum program (Figure 5). The management system for slash pine is tentative and may need to be changed to groupselection. The burn schedules are tentative in all cases. They will be imposed, monitored by inventories at 5-year intervals, and changed according to the response of unwanted vegetation 'and pine reproduction. The initial inventories and bums have been imposed in ail stands but response data are not yet available.

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