LONG-TERM EFFECTS OF A 1932 SURFACE FIRE ON STAND STRUCTURE IN A CONNECTICUT MIXED HARDWOOD FOREST[1]

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Abstract.--In 1926 woody stems ≥ 1.5 cm dbh were measured and mapped on 9 402x5 m transects (1.82 ha) in a mixed hardwood stand with abundant oak in south-central Connecticut. In 1932 a late summer fire burned approximately a third of the transects. In 1934 a post-fire inventory recorded diameter of survivors and mortality on the burned portion. In 1937 the unburned portion was similarly inventoried. Since 1957 both portions have been inventoried every 10 years. In 1926 the burned and unburned portions had approximately equal density, basal area and mean diameter. During 1926-34 84% of stems died on the burned area, mostly saplings and poles. Basal area decreased 38%. During 1926-37 34% of stems died and basal area increased 17% on the unburned area. During 1934-57 oak (28%) dominated ingrowth on the burned area. During 1937-57 maple (31%) dominated ingrowth on the unburned area. During 1934-57 surviving poles and sawtimber on the burned area grew a third faster than those on the unburned area. In 1987 the burned portion had higher density and basal area, higher absolute and relative amounts of oak and larger mean stem diameter than did the unburned portion.

INTRODUCTION

Fire has been an integral disturbance factor in eastern deciduous forests, certainly since the arrival of European colonists (Clark 1970) and possibly before (Day 1953, Buell et al 1954, Hicock and Miner 1976). Research has shown that fire can increase the relative importance of oak (Brown 1960, Swan 1970, Carvell and Tryon 1961). The ability of oaks to resprout vigorously and the thick bark on mature stems suggest oaks to be a fire-adapted species group in the Central Hardwood region. Aggressive fire exclusion programs were initiated in the early 1900's (Tillotson 1916, Stickel 1939). Conversion of oak-hickory forests to more mesophytic stands has been attributed in part to reduced wildfire frequency (Little 1973).

The immediate impact of fire is reduction of the density of small stems (Paulsell 1957, Ferguson 1961, Niering et al 1970). Larger stems may be damaged, weakened, or killed depending on the intensity and timing of a fire (Gustafson 1946, Paulsell 1957, Loomis 1973, Wendel and Smith 1986). A dense sprout and seedling layer quickly develops following the fire (Thor and Nichols 1973, Loomis 1977, McGee 1979, Teuke and Van Lear 1982, Wendel and Smith 1986).

The long-term effects of fire on the composition of mixed oak stands is less understood. We contrast 55 years of change in adjacent burned and unburned areas. We examine changes in stand level parameters: density, basal area, size class distribution, and diameter growth rates of poles and sawtimber. Finally, we describe the apparent effect of fire on selected species groups.

STUDY AREA

The Turkey Hill Tract (46 ha) is in the Cockaponset State Forest in south-central Connecticut. The tract was selected because it was typical of contemporary forests in the state, i.e. an even-aged, second-growth, mixed hardwood forest. In 1987 dominant oaks were approximately 85

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years old with individuals ranging to 110 years (Guinane 1984). Although the history before 1926 is unknown, stone walls indicate at least parts of the area were grazed and multiple-stemmed trees suggest other parts had been cutover in the past.

Most soils found in the tract are fine sandy loams characterized as being extremely stony and somewhat excessively drained to well drained. Small areas of poorly drained and very poorly drained, extremely stony fine sandy loams are found in some drainageways. Each area has been assigned to one of four soil moisture classes: moist (poorly drained), medium (well drained), dry (excessively well drained), and muck (muck and seasonally ponded). The distribution of moisture classes on burned and unburned areas is shown in Table 1. Topography varies from nearly level to locally steep with occasional rock faces. Elevation ranges from 100 to 140 m.a.s.l.

METHODS

Nine permanent strip transects were established at Turkey Hill in 1926. Transects were 402 m long and 5 m wide. Total transect area inventoried was 1.82 ha. Transects ran north-south at 100 m intervals. Stone monuments were located every 40 m along each transect. Strip maps noting the location, species and diameter of all stems ≥ 1.5 cm dbh (diameter at 1.37 m above ground) were made. Stems were mapped by stretching a 2-chain trailer tape between monuments and measuring the distance from the transect center line with graduated poles (Hicock et al 1931). Since 1926 about 0.22 ha of transect have been disturbed by roads or cutting. These areas have been excluded from the analysis.

In late summer 1932 a fire swept through the north and east portion of the tract. About 0.64 ha of transect burned. The 1934 post-fire inventory recorded all post-1926 mortality, diameter and crown classes of survivors, and any ingrowth on the burned area. The unburned area was reinventoried in 1937. Beginning in 1957 both areas were reinventoried at 10-year intervals. The minimum diameter of mapped stems has been 1.3 cm dbh since 1957. This and subsequent inventories

Table 1.--Distribution of moisture classes (ha) on burned and unburned transects of Turkey Hill Tract, Cockaponset State Forest, Ct.

Moisture Class	Transect Area Burned	Transect Area Unburned
	-------(ha)------	
Muck	0.00	0.10
Moist	0.08	0.19
Medium	0.44	0.63
Dry	0.11	0.04
Combined	0.64	0.96
Disturbed	0.10	0.12

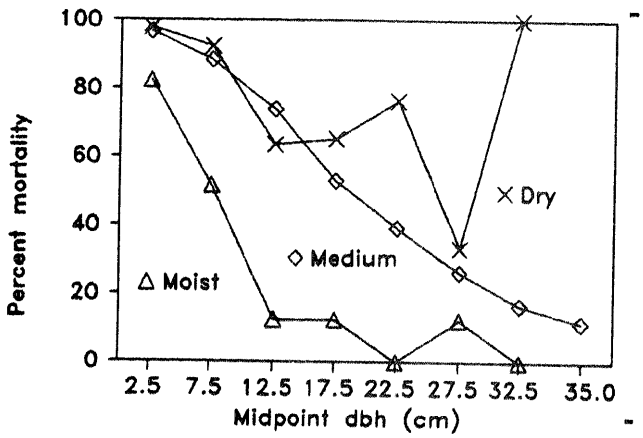

Figure 1.--Mortality (%) 1926-34 by moisture class on the burned portion of Turkey Hill Tract, Cockaponset State Forest, Ct.

recorded stem position, diameter, crown class, ingrowth, mortality, and whether or not the stem was a member of a sprout clump.

Stems were divided into three size classes: saplings (1.3-9.9 cm dbh), poles (10.0-24.9 cm dbh), and sawtimber (≥ 25.0 cm dbh). Six species groups were recognized: maple (Acer rubrum and A. saccharum); birch (Betula alleghaniensis, B. lenta, and B. papyrifera); oak (Quercus alba, Q. coccinea, Q. prinus, Q. rubra, and Q. velutina); hickory (Carya cordiformis, C. glabra, C. ovata, and C. tomentosa); mixed commercial (Fagus grandifolia, Fraxinus americana, F. nigra, Juglans cinerea, Juniperus virginiana, Liriodendron tulipifera, Nyssa sylvatica, Pinus strobus, Populus grandidentata, Prunus serotina, Sassafras albidum, Tilia americana, Tsuga canadensis, and Ulmus americana); and noncommercial (Amelanchier arborea, Betula populifolia, Carpinus caroliniana, Castanea dentata, Cornus florida, Ostrya virginiana).

Average annual mortality rates are presented instead of total inter-inventory mortality losses because of different time intervals between inventories and some large density differences between the burned and unburned areas. Because the 1934 survey recorded mortality without noting its cause, it is impossible to separate pre-fire and immediate post-fire mortality.

RESULTS

The fire did not burn with equal intensity on all soil moisture classes (Fig. 1). In particular, mortality was lower on moist sites than on medium or dry sites. Mortality on medium and dry sites was similar except for the larger diameter classes. Mortality of stems geater than 15 cm dbh was greater on dry compared to medium sites. To simplify presentation all soil moisture classes are combined in the following sections.

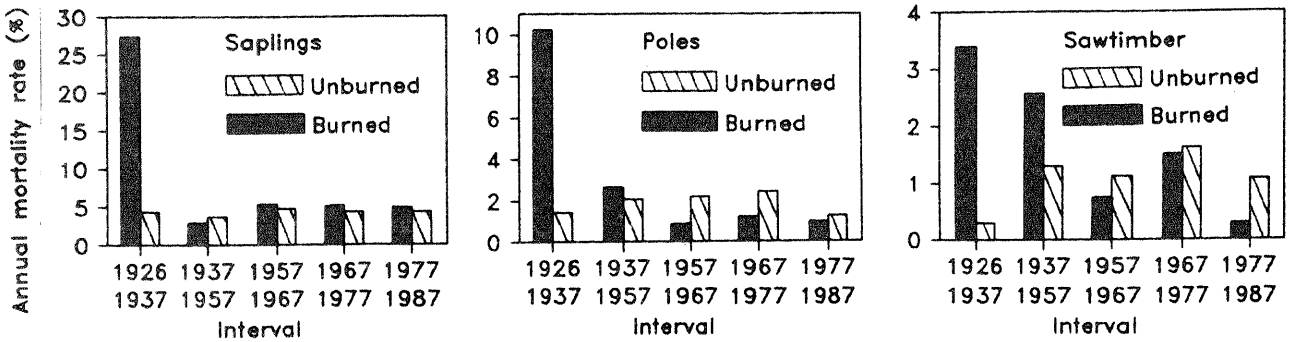

Figure 2.--Annual mortality rates (%) by size class on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct. First two mortality rates on burned portions are for years 1926-34 and 1934-57.

As might be expected, post-fire mortality was highest for saplings and least for sawtimber (Fig. 2). Since the 1930's mortality rates for saplings and poles on the unburned and burned areas have been similar. After the pulse of fire-related mortality, mortality rates on the burned and unburned areas have been similar. During 1926-34 average annual mortality of sawtimber was 11 times higher on the burned (3.4%/year) compared to the unburned (0.3%/year) area in 1926-37. Some delayed mortality of sawtimber is suspected because average annual mortality during 1934-57 was 2.6% on the burned area compared to 1.3% on the unburned area in 1937-57.

In 1926 density and basal area were similar for the burned and unburned areas: 2476 stems/ha and 17.7 m^2/ha, and 2675 stems/ha and 16.4 m^2/ha respectively (Fig. 3). Two years after the fire (1934) density was reduced by 84% and basal area by 38% on the burned area. During 1926-37 density on the unburned area fell by only 24% and basal area increased 17%. During 1937-87 density steadily decreased to 1190 stems/ha and basal area has increased to 23.6 m^2/ha on the unburned area. During 1934-57 density on the burned area increased to 3976 stems/ha. However, by 1987, density on the burned area, 1400 stems/ha, was close to the density on the unburned area. Since 1934 basal area increased faster on the burned than on the unburned portion; by 1977 basal area on the burned portion was greater than on the unburned portion.

In 1926 the distribution of stems among three size classes was similar on the burned and unburned areas (Table 2). The unburned area had slightly higher densities of saplings and poles than the burned area and a lower sawtimber density. Fire dramatically shifted size class distribution on the burned area. In 1937 on the unburned area there were 10 times as many saplings as on the burned area in 1934 due to high sapling mortality on the burned area. In 1937 the unburned area had nearly 3 times more poles and 25% more sawtimber than the burned area had in 1934.

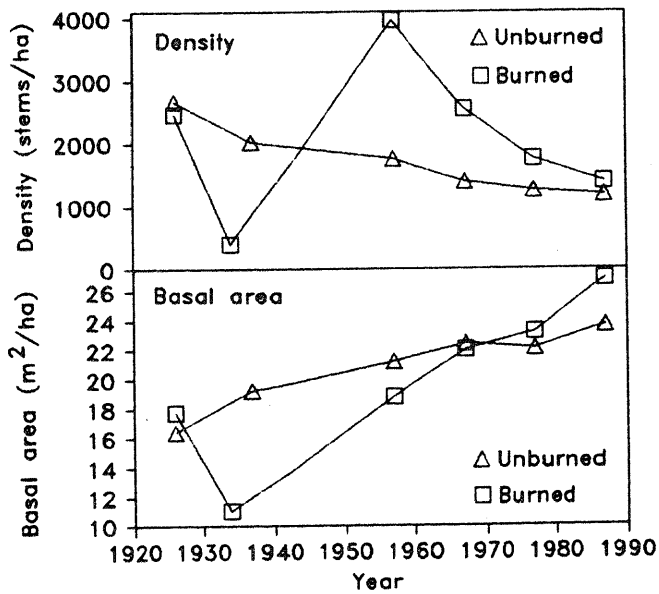

Figure 3.--Density (stems/ha) and basal area (m^2/ha) of stems (> 1.3 cm dbh) by year on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

By 1957 density had increased 2500% for saplings and 38% for poles in the burned portion, but decreased 12% for saplings and 24% for poles in the unburned portion. During 1957-87 the density of saplings on the burned and unburned areas converged. In 1987 sapling density on the burned area was nearly equal to 1977 sapling density on the unburned area. Density of sawtimber on both areas has also been converging since the fire. In 1987 sawtimber density on the burned area approached the density of sawtimber on the unburned area. In contrast, densities of poles have diverged since the fire; in 1987 there were 50% more poles on the burned as on the unburned area. The continued increase in the density of poles on the burned area is probably a lag response as

Table 2.--Density of stems (> 1.3 cm dbh) by year and size class on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

Size class	Portion	Year					
		1926	1937[1]	1957	1967	1977	1987
-(cm dbh)--		----------(stems/ha)----------					
1.3 - 9.9	Unburned	2128	1405	1241	918	823	766
	Burned	1970	140	3637	2082	1269	836
10.0 - 24.9	Unburned	481	524	399	330	291	274
	Burned	415	184	253	372	385	426
≥ 25.0	Unburned	66	100	119	147	143	150
	Burned	91	80	86	102	112	138

[1] 1934 on burned portion.

individual saplings of the numerous post-fire saplings grew into larger size classes.

Poles and sawtimber stems which survived the fire grew faster than comparable stems on the unburned area (Fig. 4). During 1926-57 stems which were poles in 1926 grew an average of 9.8 cm dbh on the burned area compared to 7.2 cm dbh on the unburned area. Since 1957 poles on both areas had approximately equal rates of diameter increase. During 1926-57 average annual diameter increase of sawtimber which survived the fire was 0.38 cm; from 1957-87 it was 0.30 cm. During 1926-57 average annual diameter increase of sawtimber on the unburned area was only 0.18 cm; from 1957-87 it was 0.19 cm.

Before the fire most species groups had similar densities on the burned and unburned areas (Table 3). Notable exceptions were higher density of hickory on the burned area and higher density of birch on the unburned area. These higher densities may have been related to the higher percentage of moist sites on the unburned relative to the burned area. Oak and noncommercial were the most numerous groups on the tract.

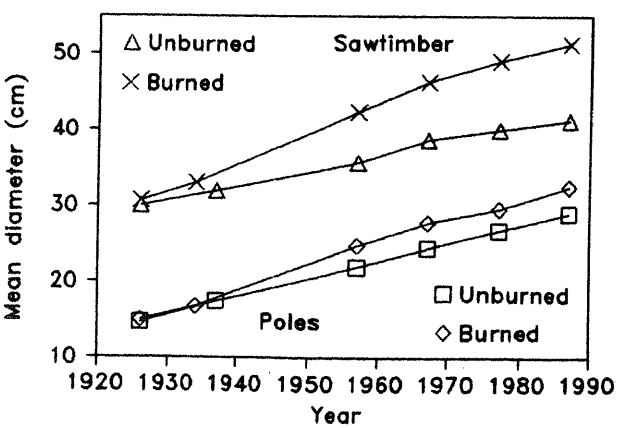

Figure 4.--Average diameter of poles (10.0 - 24.9 cm dbh) and sawtimber (≥ 25.0 cm dbh) which survived the 1932 fire on the burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

Table 3.--Density (stems/ha) in 1926, mortality (%) 1926-57 of stems (>1.5 cm dbh) recorded in 1926 and percentage of those stems which had resprouted by 1957 on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

Species group	Portion	1926 Density	1926-57 Mortality	Resprout
		(stems/ha)	--(%)--	--(%)--
Maple	Unburned	418	48.3	8.8
	Burned	374	83.9	31.2
Birch	Unburned	474	45.6	1.9
	Burned	308	82.7	17.9
Oak	Unburned	527	61.3	3.3
	Burned	570	87.8	40.6
Hickory	Unburned	90	63.8	5.6
	Burned	240	96.2	30.6
Mixed commercial	Unburned	350	71.4	1.2
	Burned	338	96.2	12.0
Noncommercial	Unburned	816	78.7	2.0
	Burned	646	99.8	17.3

The immediate impact of the fire was to drastically reduce the densities of all species groups (Fig. 5). The largest reductions were for the hickory and noncommercial species groups which had 94.1% and 99.8% fewer stems in 1934 than 1926. Other species groups had from 66.0% (maple) to 88.5% (mixed commercial) fewer stems. By comparison, density reduction from 1926 through 1937 on the unburned area ranged from 39.3% (noncommercial) to only 5.0% (maple).

There was evidence that some fire-related mortality continued through 1957 in the sawtimber size class (Fig. 2). Therefore, the comparison of species group mortality on the burned and unburned areas included all 1926-57 mortality of stems recorded in 1926. During 1926-57 mortality of all species groups was higher on the burned than on the unburned portion (Table 3). Excluding noncommercial species, mortality on the burned area averaged 41% higher than on the unburned area and ranged from 17% higher for birch to 405% greater for hickory on the burned area compared to the unburned area.

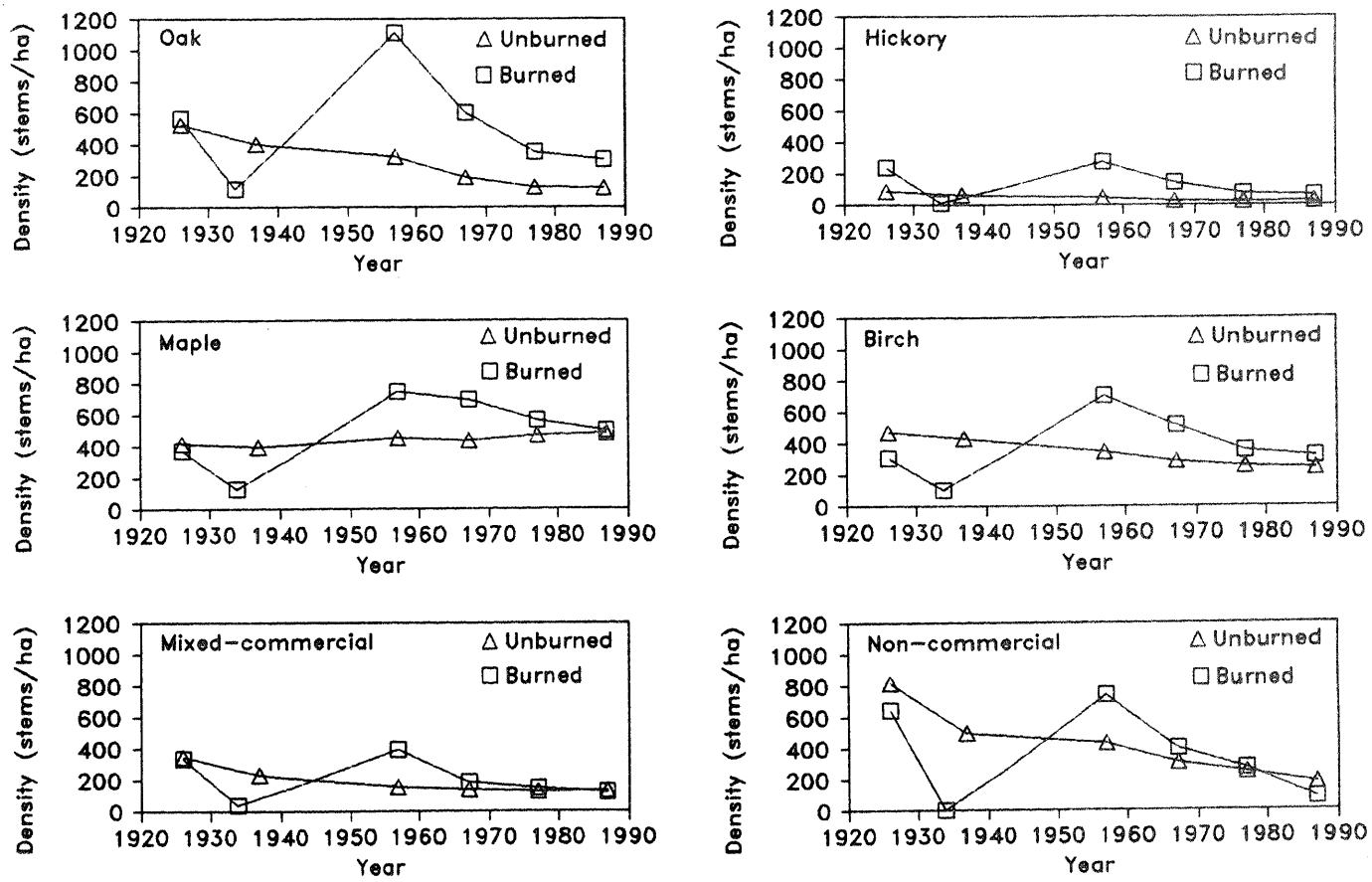

Figure 5.--Density of stems (> 1.3 cm dbh) by year and species group on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

The percentage of stems which resprouted and survived through 1957 was much higher on the burned than on the unburned portion. On the unburned portion resprouting was highest for maple (8.8%) and ranged downward to 1.2% for mixed commercial species. On the burned portion, for a given species group, the proportion of stems which resprouted ranged from 4 times (maple) to 12 times (oak) higher on the burned than on the unburned portion. Over 40% of oak stems which died before 1957 had a measurable resprout by 1957.

Recovery after the fire was rapid and by 1957 all species groups had higher densities than before the fire (Fig. 5). The density of oak, maple, and birch was at least twice pre-fire levels. Over the same time period densities on the unburned area decreased for most species groups. The exception was maple which had a small increase of 34 stems/ha.

The large amount of ingrowth on the burned area resulted from resprouting of pre-1957 mortality and new recruitment (Table 4). Ten times more oak and 20 times more hickory ingrowth was recorded on the burned than on the unburned area.

Table 4.--Density (stems/ha) of 1957 ingrowth by origin and species group on burned and unburned portions of Turkey Hill Tract, Cockaponset State Forest, Ct.

Species group	Portion	1937-57 Ingrowth origin[1] Sprout	Non-sprout	Sprout origin
		----(stems/ha)----		-(%)--
Maple	Unburned	95	112	46
	Burned	467	218	68
Birch	Unburned	44	29	60
	Burned	146	501	23
Oak	Unburned	22	79	22
	Burned	471	571	45
Hickory	Unburned	4	9	31
	Burned	105	162	39
Mixed commercial	Unburned	17	33	34
	Burned	101	282	26
Noncommercial	Unburned	108	119	48
	Burned	465	273	63

[1]1934-57 ingrowth on burned portion.

In addition, the burned area had 492 stems/ha more oak ingrowth of non-sprout origin than did

the unburned area. The proportion of all ingrowth that were resprouts of pre-1957 mortality was higher on the burned portion for oak, maple, and noncommercial species. Ingrowth of birch and mixed commercial (32% Liriodendron tulipifera) on the burned portion appeared to be from seed rather than sprouts.

During 1957-87 the trend of decreasing densities of most species groups was observed on both the burned and unburned portions. Again, maple, which increased an additional 28 stems/ha, was the exception. By 1987 the density of three groups (maple, mixed commercial and noncommercial) was the same on the burned and unburned portions. In 1987 on the burned area oak and birch densities were at the 1957 levels of the unburned area and hickory density was at the 1937 level of the unburned area. Thus we find that 55 years after the fire the burned portion had higher relative and absolute levels of oak, birch, and hickory than the unburned portion.

DISCUSSION

This study indicates that mixed hardwood stands with abundant oak can quickly recover from a major disturbance such as a summer fire and, after a moderate time period (relative to the lifespan of the dominants and codominants), have stand characteristics which approach those of undisturbed areas. Fifty-five years after the fire the burned and unburned portions could not be distinguished by either density or basal area values. In 1987 densities of maple and mixed commercial species groups were similar on the burned and unburned areas. The major long-term effect of the fire was to increase oak and hickory by 240%, increase birch by 30%, and decrease noncommercial species by 50%. Although Turkey Hill has been defoliated at least 3 times since the 1950s and there was a decade of drought from the late 1950s through the early 1960s (Stephens and Waggoner 1980), the effect of these disturbances has been negligible compared to fire-induced structural changes (Figs. 3 and 5).

Perhaps the most important finding from a silvicultural viewpoint is the ingrowth and persistence of oak following the burn. In another study in Connecticut oak seedling density increased after one prescribed burn.[3] Ten years after a fire in Missouri absolute oak density increased although the relative amount of oak decreased (Loomis 1977). In Rhode Island relative oak density was twice as high in burned areas compared to unburned areas (Brown 1960). In West Virginia increased oak regeneration on disturbed areas (including lightly burned) was attributed to increased light (Carvell and Tryon 1961). McGee (1979) reported that relative and absolute oak density in Alabama was higher in a clearcut which had been burned than the control clearcut. A lag time in which top-killed oak were resprouting may explain his short-term observation that the stocking of oaks over 4.5 feet in height was reduced three years after the fire. These findings do not necessarily conflict with the southern practice of prescribed burning to control hardwood understories. Research there has indicated more than one fire is necessary to control hardwoods (Chaiken 1952, Lotti et al 1960). However, oak regeneration is not always enhanced by fire (Teuke and Van Lear 1982, Wendel and Smith 1986). Therefore, the challenge is to find what factors interact with burning to affect oak regeneration density.

Delayed mortality of the sawtimber stems has been reported for New York (Swan 1970) and for Missouri, West Virginia and Pennsylvania (Loomis 1973), and may be related to introduction of disease through fire scars (Hepting 1941). Unfortunately, stem defects were not recorded on Turkey Hill until 1957. Olson (1965) reported that codominants and dominants on the burned area had twice as many stem and crown defects (41%) in 1957 as those on the unburned area (20%). However, the increased percentage of stem defects does not appear to have adversely affected diameter growth.

Stocking, as defined by Gingrich (1971), on the burned area was 100% before the fire and less than 50% after the fire. The increased diameter growth of poles and sawtimber at Turkey Hill may be related to the "heavy thinning" effect of the fire. There have been conflicting reports on the effect of fire on diameter growth of surviving trees. Increased growth on surviving stems was observed following a single fire in Pennsylvania (Perry and Coover 1933). Jemison (1944) reported that growth of black oak and white oak was not affected by wound size, but wounding could decrease growth of scarlet oak in the southern Appalachians. Paulsell (1957) reported that diameter growth of red oak poles was significantly reduced after two fires at five-year intervals in the Missouri Ozarks.

MANAGEMENT IMPLICATIONS

The long-term consequences of burning of mixed hardwood stands with abundant oak in southern New England appears to be a mixture of favorable and detrimental effects. On the positive side there was a more than two-fold increase in oak and hickory regeneration in the resultant stand after a late summer fire. Trees which survived the fire grew faster than comparable trees on the unburned portion. On the negative side there was a large increase in stem defects and the resulting cull may have more than offset any increased growth. From a timber management viewpoint, it appears that a single late summer fire had a neutral long-term effect on the stand.

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