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Effects of Burning on Ozark Hardwood Timberlands

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SUMMARY AND CONCLUSIONS

In 1949, the Department of Forestry initiated a study at University Forest in Butler County to yield quantitative information on the effects of fire on a timber stand. The treatments were (1) check, (2) burned annually in the spring, and (3) burned every fifth year.

The main results and conclusions are:

1. The differences between the mortality on each of the treatments and the control plots are highly significant by analysis of variance tests. Most trees which died on all treatments were in the 1.6 to 4.5-inch class. Scarlet oak and southern red suffered the greatest mortality. It appears that differences in growth rate attributable to fire were confined to the smaller trees at this early stage of the study.

2. On the periodically burned plots, 34.5 percent of the surviving trees had fire scars (resulting from two burns). On the annually burned plots, 27.2 percent of the surviving trees had developed fire scars. The more desirable species appeared to be more susceptible to scarring.

3. The main effect on the reproduction size classes was to "knock back" the larger stems. These usually resprouted and were killed again by the next fire.

4. Soil pH changes were slight. Following the burning there was slightly increased alkalinity in the surface layer. Litter remained at a minimum on the annually burned plots. The soil animals on the check plots continued to decompose the litter.

5. The unburned plots absorbed water four and one-half times faster than the annually burned areas.

6. Burning resulted in an increase in the number of species and the number of individuals of most species of grasses and forbs. Although the total number increased, a high percentage were of extremely low value as forage.

7. There was a greater occupancy by mosses on the burned plots than on the check plots.

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This bulletin reports on School of Forestry
Research Project 75, "Rehabilitation
of Missouri Forests."

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LEE K. PAULSELL

Abusive practices on the forest lands of Missouri have contributed to the extremely low productivity of thousands of acres of timberland. Ranking high among these practices has been the "burning over" of forest lands each year by fires of many and varied origins. Advocates of fire protection condemn wildfire as it occurs in Missouri for a number of reasons. Fire destroys wildlife and its habitat and is conducive to soil erosion because it removes the protective layer of litter and vegetation, and indirectly increases the rate of water run-off. Many types of wildfire actually kill or damage standing trees. The main cause of cull in Missouri timber is decay following basal damage by fires. Perhaps the most important effect of these fires has been the exposure of wood in standing trees to attack by wood-rotting fungi (Burns 1955).

In 1949, the Department of Forestry initiated a study at University Forest in Butler County to yield quantitative information on the effects of fire on a timber stand. A replication of that study was established in 1951. Although these studies are young compared to the history of fire in Missouri, they are yielding certain preliminary information which is the basis of this report.

A DESCRIPTION OF THE STUDY

A block containing six plots, each 0.4 acres in size, was established in 1949 in a moderately well-stocked, all-aged stand of the oak-hickory type on an upland "flatwoods." Site index for scarlet oak was estimated to be about 60. Initially, litter and duff measured about 3.0 inches deep. Observation and investigation indicated that the study area had not burned for about 20 years and had been closed to grazing for 10 to 15 years.

Three treatments involving two plots each were randomly assigned to the six plots. The treatments were (1) check (2) burned annually in the spring and (3) burned every fifth year. The two burning treatments were first applied in 1949 and have proceeded according to the plan since then.

The plots were burned in late afternoon on days of moderate to high fire danger. Without exception, the plots were burned during periods of fire occurrence in the immediate vicinity. Burning was often difficult on the annually burned plots due to the small amount of litter on the plots.

The litter on these plots appeared to have a tendency to drift and gather in patches on the bare ground.

Observations during the burning suggested that the fire on the annually burned plots probably did not correspond in a strict sense to a sweeping wildfire covering a large area. Due to the small area burned and limited fuel, the annual fires did not have an opportunity to gain the momentum and draft of large fires common to many parts of the Ozark region. It is believed, however, that annual fires as they occurred on these plots were typical of the numerous fires set by Ozark landowners to burn off their lands each spring. These test fires probably were typical of many fires which are controlled, while small, by efficient fire crews over the state.

MORTALITY AND GROWTH

Prior to the first burning, all trees 1.6 inches in diameter at breast height and larger were identified with aluminum tags and recorded. Records included species, diameter at breast height, total height, crown class, and notes on existing fire scars, defects and other condition characteristics. Subsequent observations and measurements were taken periodically, and complete remeasurements were made after the fifth and eighth growing seasons. Stand and stock tables were prepared as a basis for a comparison of volume change and mortality.

Before discussing mortality by treatments, mention must be made of the severe drouth conditions which began in 1952 and continued through four growing seasons. This prolonged drouth accounted for high mortality in many stands of timber throughout Missouri. It was difficult to accurately separate drouth mortality from mortality due to burning because, in many cases, the death of a tree may have been due to a combination of both conditions.

Mortality on the plots was last recorded in August 1956 and is presented in Table 1. Of the original trees that measured 1.6 inches d.b.h.

TABLE 1. MORTALITY OF TREES 1.6 INCHES D.B.H. AND LARGER, 1949-1956

Plot Number	Number of Live Trees 1949	Number of Live Trees 1956	Number of Dead Trees 1956	Mortality, Percent 1949-1956
		Control		
3	169	145	24	14.2
4	250	214	36	14.4
Average				14.3
		Annual burn		
5	231	173	58	25.1
6	280	205	75	26.8
Average				26.0
		Periodic burn		
1	214	143	71	33.2
2	193	134	59	30.6
Average				31.9

and over on the two control plots, 14.3 percent were dead. On the annually burned plots, 26.0 percent were dead and on the periodically burned plots, 31.9 percent were dead. The differences in mortality between treatments and control plots are highly significant by analysis of variance tests.

Table 2 shows that 80.0 percent of the trees which died on the control plots due to drouth and other normal causes were in the 1.6 to 4.5-inch diameter class. On the four plots which were burned (annually and periodically) about 88.0 percent of the trees which died were in the 1.6 to 4.5-inch class.

TABLE 2. MORTALITY PERCENT BY TREATMENTS AND D.B.H. CLASSES FOR ALL SPECIES 1949 - 1956

D.B.H.	Treatment		
Class, Inches	Control	Annual Burn	Periodic Burn
1.6 - 4.5	80.0	88.0	88.5
4.6 - 6.5	6.7	6.8	8.5
over 6.5	13.3	5.2	3.0

Table 3 segregates mortality by species and diameter classes. Here again it is evident that the greatest mortality was in the smaller diameter classes. Scarlet oak and southern red oak appear to have suffered the greatest mortality on the burned plots with black oak ranking third. Hickory and post oak suffered the least mortality on the burned plots. Hence, the more desirable species were most affected while species of lesser value fared much better. This can account in part for the poor composition of many Missouri stands.

It is difficult to anticipate this early in the life of the study what the effects of the burning will be on growth. Years of drouth have reduced growth in most Missouri stands. Since the stand under investigation is all-aged, it contains a number of trees over 20 inches d.b.h. which are generally of low quality and vigor. On certain plots, one or more of these trees have died—probably due to drouth or other natural causes. The death of a tree of this size may remove 50 to 60 cubic feet from the 1956 volume; at the same time, this amount must be added to the volume lost through mortality. These larger trees were a part of the stand and must receive consideration. However, their inclusion or elimination introduces serious difficulties in an analysis of growth on the plots of relatively small size.

In an attempt to clarify the effect on growth, volumes were computed by treatments for 1949 and 1956 of all trees up to and including the 12-

TABLE 3. MORTALITY PERCENT BY SPECIES, DIAMETER CLASSES AND TREATMENTS, 1949 - 1956

D.B.H. Class, Inches	Control	Mortality, Percent Annual Burn	Periodic Burn
		Scarlet oak	
1.6 - 4.5	26.3	50.0	73.3
4.6 - 6.5	---	---	40.0
Over 6.5	50.0	---	50.0
All classes	30.4	50.0	63.6
		Black oak	
1.6 - 4.5	35.6	50.3	57.4
4.6 - 6.5	18.2	33.3	33.3
Over 6.5	45.4	33.3	10.0
All classes	34.9	45.7	47.7
		Southern red oak	
1.6 - 4.5	38.5	71.6	77.5
4.6 - 6.5	100.0	30.8	37.5
Over 6.5	---	80.0	11.1
All classes	43.8	66.7	61.4
		White oak	
1.6 - 4.5	---	21.7	46.2
4.6 - 6.5	---	---	---
Over 6.5	---	---	---
All classes	0.0	17.9	37.5
		Hickory	
1.6 - 4.5	7.0	2.9	18.6
4.6 - 6.5	---	---	---
Over 6.5	3.6	---	---
All classes	5.2	2.5	13.7
		Post oak	
1.6 - 4.5	1.0	10.6	21.7
4.6 - 6.5	---	---	8.3
Over 6.5	---	---	5.9
All classes	0.8	7.5	18.0
		Other	
1.6 - 4.5	---	33.3	20.0
4.6 - 6.5	---	---	---
Over 6.5	---	---	---
All classes	0.0	20.0	16.7

TABLE 4. VOLUME AND PERIODIC VOLUME INCREASE PER ACRE BY TREATMENTS, TREES 1.6 - 12.5 INCHES D.B.H. INCLUSIVE

Treatment	Net Volume, Cubic Feet		Volume Increase, 1949-1956	
	1949	1956	Cubic Feet	Percent
Control	724.12	839.88	115.76	16.0
Annual burn	698.50	777.75	79.25	11.3
Periodic burn	729.00	756.62	27.62	3.8

inch d.b.h. class. This information is presented in Table 4. The growth, based on total volume in 1949, was 16.0 percent for the control plots, 11.3 percent for the annually burned plots, and 3.8 percent for the periodically burned plots. It should be understood that this relative periodic growth is not meant to apply to the entire plot inventory but rather to those trees up to and including the 12-inch d.b.h. class.

A second method was used to determine the effect of fire on growth. Since changes in volume did not clearly express the effects, d.b.h. growth by species and treatments was examined. Average d.b.h. growth and average d.b.h. within 1.0-inch d.b.h. classes were plotted for three species groups by treatments. Curve values were then read for 3.0, 4.0, and 5.0 inch trees. These values are given in Table 5. The periodic d.b.h. increase

TABLE 5. AVERAGE PERIODIC D.B.H. INCREASE BY SPECIES GROUPS AND TREATMENTS

D.B.H., Inches	D.B.H. Increase, Inches		
	Control	Annual Burn	Periodic Burn
		Red oak group	
3.0	.82	.75	.63*
4.0	1.10	1.00	.93*
5.0	1.32	1.19	1.16
		White oak group	
3.0	.51	.49	.42
4.0	.67	.65	.60
5.0	.79	.76	.74
		Hickory	
3.0	.42	.41	.35
4.0	.48	.51	.43
5.0	.54	.58	.48

*Significant at 5% level.

in practically all cases was less on the burned plots than on the control plots. The only statistically significant difference occurred in the black, scarlet and southern red oak group. The significant difference (at 5% level) occurred between the unburned and the periodically burned plots on trees 3.0 and 4.0 d.b.h. Therefore, at this stage of the study, differences in growth attributable to fire appear to be confined to the smaller trees.

Somes and Moorhead (1950), in discussing prescribed burning in oak-pine stands in southern New Jersey, indicated that there was no apparent effect on tree growth.

Perry and Coover (1933) found a reduction of 60 to 75 percent in volume growth of trees on frequently burned sites as contrasted with similar trees on protected sites, despite the wider crowns and greater growing space on the burned areas.

Not only is earlier literature somewhat conflicting, the early effects of fire on timber production may also be conflicting. Fire scarring and infestation by insects and fungi may account for decreased vigor of trees and consequent growth reductions. The reduction of the understory—a heavy user of water—may release more water for use by the larger trees. On the other hand, the annual removal of litter increases surface runoff and evaporation of soil moisture. In drouth periods much of the moisture may evaporate before it reaches the root zone.

Any over-all interpretation of the effects of fire on growth of a timber stand will require the investigation of several interrelated factors, the net effect of which may not become pronounced for a considerable period of time.

These data on mortality and growth strongly suggest that long term timber management for the production of high quality wood products from a maximum proportion of desirable species may be seriously affected by fire.

VISIBLE FIRE DAMAGE TO STANDING TREES

Even casual observation on most burned areas reveals that surface fires damage standing trees. Damage may vary in intensity from minor scorching of the bark to complete consumption of the tree by the fire. A surface fire often kills a portion of the cambium near the base of a tree, causing the death of a portion of its circumference. The bark usually sloughs after several years, affording easy entrance to insects and rot-causing fungi.

Hepting (1935) listed three effects of fire scars on hardwoods: (1) a mechanical weakening due to the cessation of increment over the scarred area; (2) an interruption in the normal physiological function of translocation of food, nutrients and water; and (3) most important of all, the tree is exposed to the entrance of wood-destroying fungi and insects.

Hedgcock (1927) found that more than 90 percent of all basal or butt rots in hardwood forests entered through fire scars.

Toole and Furnival (1957) pointed out that the most important cause of cull in southern hardwood forests was heart rot that developed from wounds made by fire.

Rot-producing fungi cannot penetrate sound, healthy bark. When wood is exposed, however, spores may become established and decay begins. The cambium surrounding the damaged area produces callus tissue which may close over the scar. Decay which gained entrance due to the fire continues to destroy the wood long after the surface has healed over.

A great variety of insects, including ants and termites, finds suitable entrance through the fire scar and damaged wood. In many cases, decay and insects combine forces to cause rapid, serious damage to standing trees. Grub channels and pin worm holes seriously reduce the grades of lumber and other products produced from the standing tree.

The periodically burned plots were first burned in the spring of 1949 and again in 1953. Of the trees surviving in early 1957 (prior to the 1957

Figure 1—Recent fire scar on a black oak on a periodically burned plot. This scar resulted from death of the cambium due to intense heat. Damage to the cambium often is not evident until the bark cracks and sloughs after a year or two. Insects and decay find easy access through a fire scar such as this. (Photo by Wildon E. Roberts.)

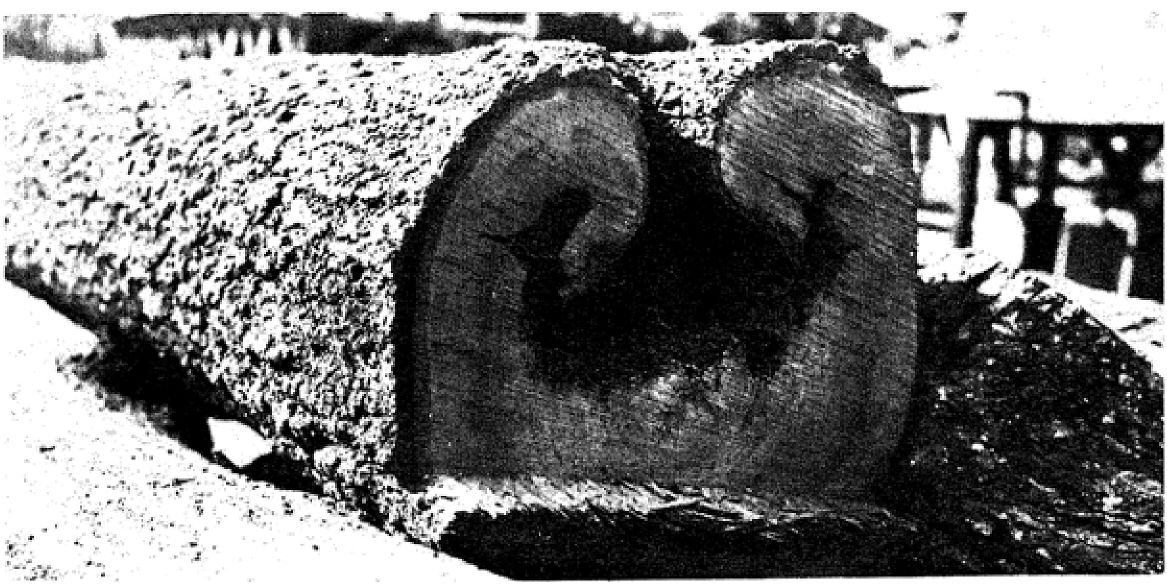

Figure 2—Lower end of a black oak butt log, approximately 20 inches in diameter at the stump. The defect is due to rot-causing fungi and insects which had ready access to the interior of the log. Callus tissue formed following the fire damage but failed to close over the wound. Much of the lower 5 feet of this log will be wasted.

burn), 34.5 percent had developed fire scars. Thus, as a result of two fires almost one-third of the trees were killed either directly or indirectly (Table 1) and over one-third of the remaining trees were damaged.

On the annually burned plots, 26.0 percent of the trees were killed and 27.2 percent of the surviving trees developed scars as a result of eight annual burns. In both treatments it should be borne in mind that the total number of trees on each treatment has been greatly reduced since the establishment of the study. The percentages given above take into account only the trees living in early 1957.

Table 6 indicates that the desirable species (white oak, scarlet oak, black oak and southern red oak) appear to be more susceptible to basal scarring than the less desirable species (post oak and hickory). Post oak is noted for its thick, coarse basal bark. Very few scarlet oaks existed at the time of the fire scar examination since the mortality of this species was high. Thus, the scarlet oak percentages given in Table 6 are not too reliable. Observations on other burned areas substantiate the evidence that scarlet oak is highly susceptible to basal fire scars.

TABLE 6. PERCENT OF LIVE TREES JANUARY 1957 WITH FIRE SCARS DUE TO BURNING TREATMENTS BY SPECIES AND TREATMENTS

Burning Treatment	Scarlet Oak	Black Oak	Southern Red Oak	White Oak	Hickory	Post Oak	Others
Annual	100.0	57.7	60.0	59.1	19.1	10.0	25.0
Periodic	25.0	66.7	50.0	100.0	20.5	23.3	40.0

EFFECT ON TREE REPRODUCTION

One common reason for the age-old custom of burning woodlands in Missouri has been the belief that sprouts and young trees may be eliminated. Many Ozark landowners attempt to clear land by a combination of cutting and burning. In many cases, the cleared land is not suited to cultivation and there follows a constant battle against sprouts that invade the sub-marginal field. Closer examination often indicates that the sprouts are of the less desirable species and when the land is abandoned, an inferior stand develops.

Observation of many young stands following fires or repeated burnings indicates that the species composition has changed significantly from the original stand. Species such as blackjack oak, hickory, post oak and a variety of pioneer species may have a greater representation.

An attempt was made in this study to observe the effects of fire on the reproduction sizes. Sixteen permanent mil-acre plots were established for each treatment. Seedlings, sprouts and sprout clumps were tallied by species and size classes. Maps were prepared showing the location of the stems.

Due to an insufficient number of stems of certain species it is impossible to make a definite comparison of resistance to the fire of the various species. Members of the red oak group appeared to be least tolerant of fire. Although they sprouted back, in most cases they seemed unable to maintain themselves in the stand as well as hickory and post oak. Hickory and post oak actually showed a slight increase from 1949-1956. This can be observed on many areas which have been burned. Post oak, in particular, appears to have a more fire-resistant bark than the red oaks and it also appears to sprout prolifically following top-kill by fire.

Table 7 provides a comparison of the abundance of reproduction by size classes. Burning caused a significant reduction in the percentages of

TABLE 7. RELATIVE ABUNDANCE OF SPROUTS AND SEEDLINGS BY SIZE CLASS AND TREATMENT, EXPRESSED IN PERCENT OF TOTAL NUMBER OF STEMS

	Control		Annual Burn		Periodic Burn	
Size Class	1949	1956	1949	1956	1949	1956
Under 2.0' (ht.)	31.8	42.4	30.0	76.7	26.0	76.4
2.0' - 4.5' (ht.)	9.1	15.2	20.0	10.0	28.0	21.8
0.1" - 1.5" (d.b.h.)	59.1	42.4	50.0	13.3	46.0	1.8

stems 0.1 to 1.5 inches d.b.h., coupled with an increase in the stems under 2 feet in height on the burned plots. Thus, it can be seen that fire has "knocked back" the larger reproduction but that it continues to resprout.

Oak root-stocks are sturdy and in most cases are not susceptible to fire. Liming and Johnston (1944) conducted a study on the northern Clark and Mark Twain National Forests in Missouri. They found that repeated killing of the tops by fire resulted in the formation of enlarged, often distorted, callus-like structures at the ground line, often with a taproot beneath. Sprouts originating from these stools were termed stool sprouts. A large number of these stool sprout systems were dissected. It was found that the number of generations per root system averaged 4.5 and the average age of the root systems was 23.9 years.

Hepting (1935) found in young Mississippi delta hardwoods that surface fires killed many seedlings and small reproduction and that saplings and poles, because of their relatively thin bark, offered little resistance to fire.

The effect of fire on individual stems varies greatly. Of prime importance is the amount and location of the litter in relation to the tree trunk. It can be observed on the annually burned plots that litter tends to ac-

Figure 3—Unburned (control) plot, spring 1956. Note size distribution and the density of the understory. The forest floor is composed of a relatively thick layer of litter in various stages of decomposition. The surface soil is loose and porous, and has a high absorption capacity. (Photo by Wildon E. Roberts.)

cumulate in patches around stems. In many cases the stems were killed by successive fires each year. However, the living root collar may continue to resprout; these sprouts seldom grow out of the small size class.

Figures 3, 4 and 5 provide a comparison of the appearances of the plots by treatments. Figure 3 is characteristic of an unburned plot. Here can be seen trees of various ages and sizes. A relatively heavy accumulation of litter is present. Figure 4 shows a portion of an annually burned plot. The apparent absence of the smaller trees is conspicuous; although, many small sprouts exist but cannot be seen. The most striking difference in a comparison of Figures 3 and 4 is the open, storied effect on the burned plots as against the more fully stocked appearance of the unburned plots. Figure 5 is characteristic of the periodically burned plots. A great many small, leaning dead trees can be seen. Also noticeable is the mantle of sprouts near the ground which resulted from the burn of 1953. Past observations indicate that these sprouts will, for the most part, be killed back by the next periodic burn, but will resprout and develop until killed again.

Figure 4—Burned annually since 1949. Note the sparseness of smaller stems and the depth of vision possible through the understory. Remnants can be seen of trees dying since 1949. Leaf litter is scarce and the surface soil is compact. (Photo by Wildon E. Roberts.)

Figure 5—Periodically burned plot: photographed—spring, 1956; last burned—spring, 1953. Most of the small leaning trees are dead. Note sprout mantle resulting from 1953 kill. The large tree on the left has a fresh scar, which is pictured close up in Figure 1. (Photo by Wildon E. Roberts.)

SOIL AND LITTER

Preliminary to the establishment of the 1949 block of plots, a mechanical analysis of the surface soil was made, using the Bouyoucous hydrometer. This analysis was made for two levels:

Soil Depth Centimeters	Percent Sand	Silt	Clay
0-5	22	73	5
5-10	10	79	11

The reaction (pH) of the soil was measured before burning and at intervals for four years after establishment of the study. Changes in pH for the surface 5 centimeters of soil were:

Treatment	pH of Soil 1949	1953
Unburned	5.12	5.06
Annual Burn	5.17	5.68

Changes in pH for the 5 to 10-centimeter depth during this period were negligible. Annual burning during the four-year period resulted in slightly increased alkalinity in the 0 to 5-centimeter layer, which could be significant, ecologically, over a long period of time.

Heyward and Barnette (1934) found in the longleaf pine region that soils subjected to frequent fires were consistently less acid and had higher percentages of replaceable calcium and total nitrogen.

Burns (1952) also found that burning increased pH and nitrogen in New Jersey soil. He concluded that periodic burning had much less effect on the soil than did annual burning for long periods.

Any study of the leaf fall and decomposition is complicated by a great many factors. The amount of litter produced per acre is dependent upon species composition, stocking, age, site, and history of the stand. The rate of decomposition depends upon the chemical composition of the leaves, species, weather and climate, the soil animal population, stocking, and the history of the stand.

A discussion of litter as it affects infiltration of water is given in the section dealing with infiltration. The forest floor, including litter in its various stages of decomposition, is a vital part of the forest stand. Trimble and Lull (1956) described the dual function of humus. It stores and transmits moisture and it helps shield the soil against the eroding force of rainfall. Humus accumulates when the annual additions are greater than the annual decay.

Blow (1955), studying litter under oak forests in eastern Tennessee, found an average annual fall of 2600 pounds per acre. One stand with an annual fall of about 1.3 tons per acre reached a peak litter weight of 5.4 tons in December and dropped to a fairly stable low of 4.2 tons in August.

Table 8 provides a summary of litter weights per acre at various dates during the study. It can be seen that there is relatively little difference between the weight of litter on the control plots in 1949 and 1957. The August 1954 weights are considerably lower than 1953 or 1957 weights. This can be explained in part by the fact that almost a year had passed since the 1953 leaf fall, and a fairly stable low is expected in August.

TABLE 8. COMPARISON OF TOTAL LITTER WEIGHTS BY TREATMENTS

	Litter Weight, Tons Per Acre			
Treatment	March 1949	March 1953	August 1954	Jan. 1957
Control	7.45	4.95	4.37	6.69
Annual Burn	5.71	2.63	2.32	3.75
Periodic Burn	5.17	4.73	2.68	6.15

The weight of litter on the annually burned plots dropped markedly after the first burning and has remained low. At first thought, it is surprising that 2 to 3 tons of litter continues to remain on annually burned plots. Of course a certain quantity falls each year but in addition to this a small residual amount escapes burning, partly due to the patchy nature of the litter on the annual plots. Rarely, in the spring, does all of the litter burn down to mineral soil. On both the annually and periodically burned plots, another factor enters the picture. With increased mortality on the burned plots there has been an increase in the amount of woody litter. Twigs, bark and stems of smaller trees have increased the weights of the litter samples. Information on weights of the woody portion of the litter is given in Table 9. In January, 1957, woody material accounted for 40.9 percent of the total litter weight on the annually burned plots; 17.0

TABLE 9. JANUARY 1957 LITTER WEIGHTS BY TREATMENTS DIVIDED BETWEEN WOODY AND LEAFY MATERIAL

			Weight, tons/acre	
Treatment	Total Litter Weight, Tons Per Acre	Woody Material Percent	Woody Material	Leafy and Herbaceous Material
Control	6.69	8.8	.59	6.10
Annual Burn	3.75	40.9	1.53	2.22
Periodic Burn	6.15	17.0	1.04	5.11

percent on the periodically burned plots and 8.8 percent on the unburned plots.

Between periodic burns, the litter weights increased until they compared rather closely with the weights of litter on the unburned plots. With this litter build-up, the periodically burned plots could be expected to burn more vigorously with much greater heat than the annually burned plots.

When forest land is protected from fire, a large population of soil animals develops in the surface soil. Fungi and decay-causing bacteria aid this population in the decomposition and mixing of the litter into the mineral soil. This action results in the porous, absorptive condition found in unburned forest stands. As a biological equilibrium is reached, the decomposition may approximate the annual fall of litter and the litter weight on the ground may remain fairly constant except for seasonal variations.

INFILTRATION OF WATER

As the study progressed a difference in the physical appearance of the soil became more apparent. The soil on the annually burned plots became increasingly compact while the soil of the control plots continued to be loose and crumbly. Earthworm and insect activity continued on the control plots but practically ceased on the annually burned plots.

Since the physical condition of the surface soil is a prime factor in the rate at which rainfall can be absorbed by the soil, it was deemed advisable to compare the infiltration rate of the soils under the two treatments.

An adjustable head ring infiltrometer developed by Fletcher (1957) was used in making the tests. Sixteen sampling points were randomly chosen on each plot. Two readings were taken at each point. This resulted in 64 readings for each treatment. The time required for a given amount of water to move into the soil under a hydrostatic head of 30 inches was recorded for each trial. Averaging the readings and converting to cubic centimeters of water per minute furnished a comparison. On the annually burned plots the rate of infiltration was 415 cc. per minute. On the control plots, the infiltration rate was 1870 cc. per minute.

After seven annual fires, these rates indicate that the unburned areas absorbed water at a rate four and one-half times faster than the burned areas.

The reduction of the water infiltration rate is probably one of the most important effects of fire. When land is subjected to burning, the protective mantle of litter and humus is eliminated. The soil becomes compact and a crust often forms. Due to the slower infiltration rate, much of

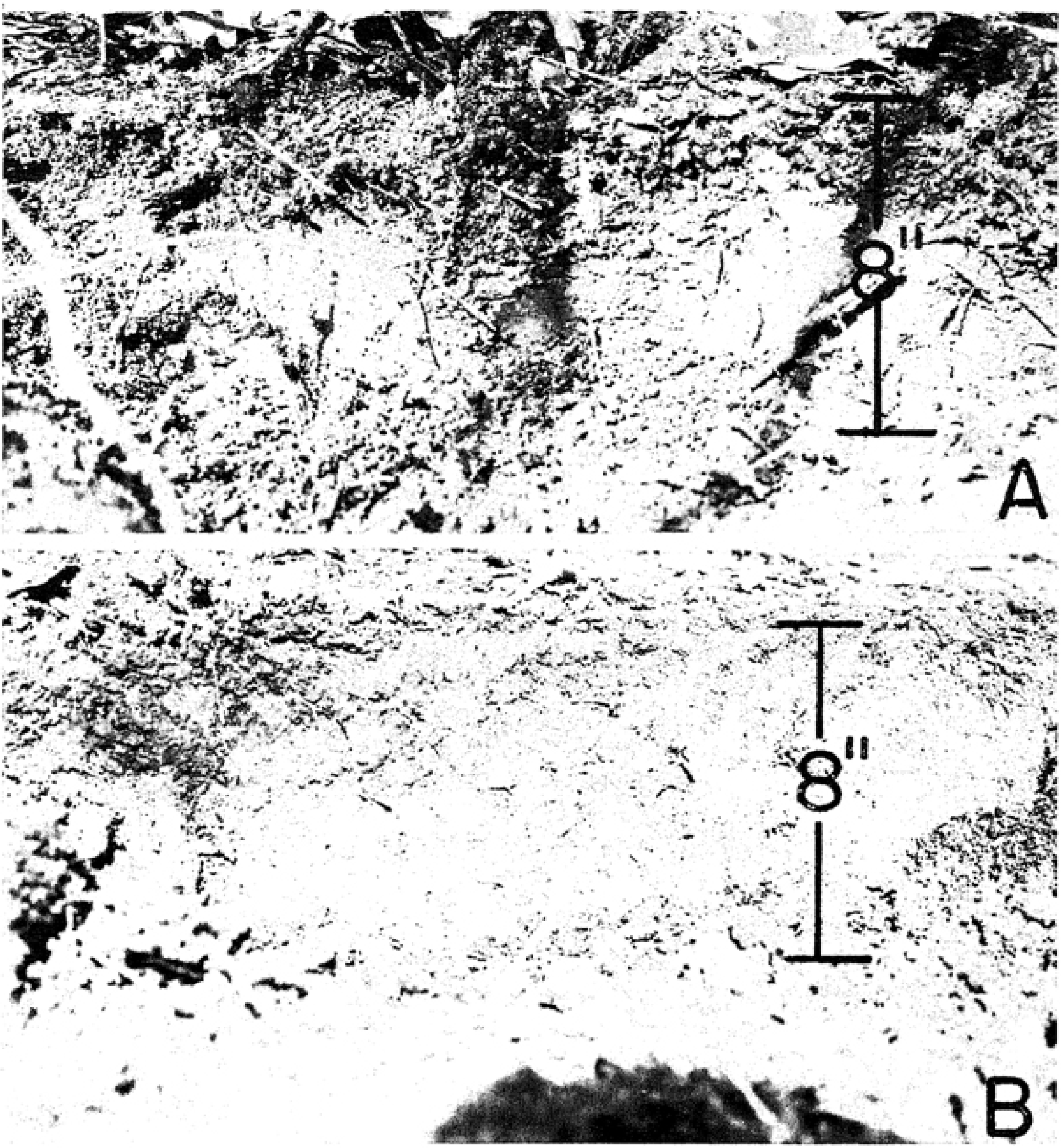

Figure 6—Photograph A shows surface soil profile 8 inches deep on the unburned plots. In addition to the visible leaves a thick layer of organic matter in various stages of decomposition can be seen at the soil surface. Earthworm activity was pronounced. Many openings existed in and near the surface. The protective mantle of litter and humus greatly aids the infiltration of water. Photograph B is a surface soil profile 8 inches deep on plots burned annually since 1949. The soil is compact and no layer of humus exists. The rate of water infiltration is much slower on this area.

the water from an intense rain runs off before it can be absorbed. During the past several years of drouth this has become increasingly important on many lands which cannot absorb rainfall due to their decreased infiltration capacity.

Heyward (1934) writing on the effect of frequent fire on chemical composition of forest soils in the longleaf pine region stated, "The mellow, permeable surface soil on unburned areas contrasted strikingly with the compact, impermeable soil on the burned areas."

Auten (1934) in northern Arkansas found soil from burned forest areas 25 percent denser than soil under undisturbed forests. The difference represented increases in compactness and corresponding losses in porosity.

Burns (1952), working in the pine barren region of New Jersey, found that frequent fire decreased the abundance of soil animals and caused compaction.

Figure 6 provides visual evidence of some of the physical characteristics of the top 8 inches of soil on the unburned and annually burned plots. Profile "A" from the unburned control plot will absorb water at approximately four and one-half times the rate of profile "B" of the burned plots. During an intense rain the water that cannot be absorbed by the soil must run off. Not only is the soil deprived of moisture but run-off water often causes erosion. Marshall (1939) conducted run-off studies in the St. Francis watershed which includes this present study. He found that comparative run-off from heavily grazed pasture was 55 percent; from moderately grazed pasture, 3.1 percent and from unburned oak forest, 1.3 percent. Erosion from the heavily grazed pasture was 70 pounds per acre; from moderately grazed pasture and unburned forest, 4 pounds per acre.

CHANGES IN HERBACEOUS AND BRYOPHYTIC VEGETATION

As the burning treatments progressed from year to year, certain changes in the herbaceous and bryophytic vegetation became evident. A survey was made of the vegetation in August, 1955. Annual burning has substantially increased the number of species and the number of individuals of most species of grasses and forbs.

This response of herbaceous cover is due in part to the opening up of the stand through mortality (Martin, Dunkeson and Baskett, 1955). It is also due in part to a reduction of the litter each year in early spring.

Arend and Julander (1948) found in northern Arkansas that the amount of ground cover appeared to vary with basal area. They found more grasses and less shrubs and vines on the poor sites than on the good sites. This probably was related to the decreased moisture usually associated with the poorer sites.

Read (1951) found in the Arkansas Ozarks that herbage in freshly burned woods was 45 percent weeds or forbs in the first growing season following fire and was 33 percent weeds or forbs in unburned woods.

TABLE 10. FREQUENCY (F) AND DENSITY (D) OF HERBACEOUS AND SHRUB COVER ON 16 MILACRE PLOTS BY TREATMENTS *

Species	Annual Burn		Control		Periodic Burn		Estimated Forage Value
	F	D	F	D	F	D	
Danthonia spicata	25	30	12	2	25	7	not grazed
Panicum philadelphicum	12	22	--	--	--	--	fair
P. anceps	6	1	--	--	--	--	fair
P. linearifolium	19	32	6	1	6	1	fair
P. laxiflorum	31	29	6	1	31	9	fair
P. tennesseense	12	24	--	--	6	3	fair
P. barbulatum	38	29	12	5	19	29	fair
P. commutatum	19	8	--	--	12	34	fair
P. Ashei	6	78	6	1	25	29	fair
Andropogon spp.	31	31	25	10	12	8	good
Carex artitecta	31	35	12	2	6	4	fair
Juncus sp.	6	4	--	--	--	--	
Smilacina sp.	--	--	6	1	--	--	
Agave virginica	6	1	--	--	--	--	
Anemonella thalictroides	6	7	--	--	--	--	
Potentilla simplex	6	1	6	1	6	1	
Rubus sp.	6	1	--	--	--	--	fair
Cassia fasiculata	6	4	--	--	--	--	not grazed
Baptisia leucophaea var. laevicaulis	6	1	--	--	--	--	not grazed
Crotalaria sagittalis	--	--	--	--	6	1	not grazed
Tephrosia virginiana	6	1	6	2	6	1	not grazed
Smilax glauca	25	27	--	--	12	3	poor
Gillenia stipulata	--	--	12	2	6	3	
Rosa carolina	6	1	6	1	18	4	poor

Desmodium sp.	--	--	--	--	6	1	fair
Lespedeza sp.	--	--	6	1	--	--	fair to good
L. violacea	19	11	6	2	38	36	fair to good
L. virginica	38	19	6	3	6	5	fair to good
L. stipulacea	--	--	--	--	6	1	fair to good
Galactia volubilis	12	6	--	--	6	1	
Oxalis sp.	6	9	--	--	--	--	
Acalypha gracilens var. monococca	62	52	--	--	18	9	not grazed
Erphorbia corollata	12	2	6	1	--	--	not grazed
Rhus aromatica	--	--	12	2	--	--	poor
R. radicans	6	1	--	--	--	--	poor
Parthenocissus quinquefolia	--	--	6	1	--	--	
Vitus aestivalis	6	1	--	--	6	1	fair
V. sp. (seedling)	6	1	--	--	--	--	fair
Ascyrum hypericoides	12	2	--	--	--	--	not grazed
Viola emarginata	6	2	--	--	--	--	
Vaccinium vacillans	12	5	--	--	--	--	fair
V. sp.	--	--	6	3	--	--	fair
Monarda Russeliana	--	--	6	1	--	--	poor
Cunila origanoides	--	--	6	1	--	--	not grazed
Ruellia strepens	--	--	--	--	6	2	not grazed
Lobelia inflata	6	1	--	--	--	--	
Solidago sp. (rosette)	12	7	--	--	12	3	not grazed
S. sp.	12	2	--	--	--	--	
Aster sp.	--	--	--	--	6	1	
Antennaria plantaginifolia	3	16	25	41	31	111	not grazed
Gnaphalium purpureum	--	--	--	--	6	1	
Helianthus stromosus	25	10	12	3	--	--	fair

*Nomenclature is that of "Gray's Manual of Botany", 8th Ed., 1950, by M. L. Fernald. Dr. C. L. Kucera of the Dept. of Botany, Univ. of Missouri, verified the identifications.

Grasses comprised about the same portions, 20 and 22 percent, in both burned and unburned woodland. Ozark forest ranges generally have more weeds than grasses. Read (1951) further indicated that only 22 to 26 percent of the herbage in burned woodlands was considered edible as contrasted with 50 percent or more on an unburned open bluestem grass meadow. Grazing capacity varied from 10 to 40 acres per cow-month in medium to well-stocked, good hardwoods to 4 to 6 acres per cow-month in moderately grazed, sparse, poor hardwoods. This can be contrasted with findings which indicate that about one acre per cow-month is required in years of normal rainfall on unburned, open, native grass "meadows."

Table 10 summarizes the frequency and density of herbaceous and shrub cover by treatments. Forage values also are included in the table. It is apparent from this table that there has been a significant increase in grasses and forbs on the burned areas. Further study indicates that a large number are classed as "not grazed" or "poor." It is estimated that grazing capacity on the annually burned plots would be 6 to 10 acres per cow-month. The gain in forage is negligible in dense, good hardwoods stands, which furnish only incidental grazing in any case (Read 1951).

Also of interest in the 1955 survey was the fact that there had been a pronounced shift in the degree of moss occupancy. Total occupancy by mosses was quite high on the periodically burned plots and much higher on the annually burned plots.

The exact role of mosses in a forest community has received little attention. The importance of mosses as related to the germination of seeds may vary widely. Smith (1951) has demonstrated that polytrichum mosses and moist mineral soil make better seedbeds than white pine litter, lichens, and dry mineral soil. In contrast, Roe (1948) points out that sphagnum moss retards black spruce regeneration.

Observations indicate that patches of moss may act as deterrents to the accumulation of hardwood litter. Leaves falling on moss areas do not contact mineral soil; matting does not occur and they dry out quickly. Wind action often keeps moss areas free of leaves.

Since oak acorns are relatively large and heavy, they tend to remain where they fall. Acorns dropping on areas of moss may often be damaged by freezing and are convenient food for rodents and other forms of wildlife. From these standpoints, moss areas may hinder the establishment of oak seedling reproduction.

Table 11 provides a summary of moss frequency and relative areas.

TABLE 11. FREQUENCY (F) AND AREA OF BRYOPHYTIC AND LICHEN COVER ON 16 MILACRE PLOTS BY TREATMENTS.*

	Annual Burn		Control		Periodic Burn	
Species	F	Area sq. in.	F	Area sq. in.	F	Area sq. in.
Atrichum angustatum	38	151.0	6	0.1	31	189.0
Brachythecium oxycladon	--	---	-	--	-6	5.0
Campylium hispidulum	--	---	-	--	12	2.0
Dicranella heteromalla	31	98.0	-	--	--	---
Ditrichum pallidum	38	64.0	6	3.0	31	60.5
Fissidens minutulus	--	---	-	--	6	0.1
F. taxifolius	--	---	6	1.0	6	2.5
Weisia viridula	12	6.0	--	---	19	18.0
Cladonia sp.	19	48.0	6	1.5	6	0.5

*Nomenclature is that of "Missouri Bryophytes" by L. J. Gier, Trans. Kans. Acad. Sci. 58(1) 1955, Dr. L. J. Gier of the Biology Dept., Wm. Jewell College, verified the identifications.

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