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FIRE CONTROL NOTES

A PERIODICAL DEVOTED
TO THE TECHNIQUE OF
FOREST FIRE CONTROL

FOREST SERVICE • U. S. DEPARTMENT OF AGRICULTURE

FORESTRY cannot restore the American heritage of natural resources if the appalling wastage by fire continues. This publication will serve as a channel through which creative developments in management and techniques may be communicated to and from every worker in the field of forest fire control.

Volume 18 **Number 2**

FIRE CONTROL NOTES

A Quarterly Periodical Devoted to the

TECHNIQUE OF FOREST FIRE CONTROL

The value of this publication will be determined by what Federal, State, and other public agencies, and private companies and individuals contribute out of their experience and research. The types of articles and notes that will be published will deal with fire research or fire control management: Theory, relationships, prevention, equipment, detection, communication, transportation, cooperation, planning, organization, training, fire fighting, methods of reporting, and statistical systems. Space limitations require that articles be kept as brief as the nature of the subject matter will permit.

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SOME PRINCIPLES OF COMBUSTION AND THEIR SIGNIFICANCE IN FOREST FIRE BEHAVIOR

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Combustion chemistry

Although a large fire is essentially a physical or meteorological phenomenon, combustion itself is a chemical chain reaction process, which takes place at high temperatures. In all forest fires, large or small, materials such as leaves, grass, and wood combine with oxygen in the air to form combustion products plus large quantities of heat. Heat, as we shall see, is the most important combustion product in fire behavior.

There are three rather definite phases of combustion, although they overlap somewhat and all exist simultaneously in a moving fire. First comes the preheating phase in which fuels ahead of the fire are heated, dried, partially distilled, and ignited. In the second phase, the distillation of gaseous substances continues but is now accompanied by their burning or "oxidation." Ignition might be regarded as the link between the first, or preheating, phase and the second, or gaseous, combustion phase. Ignition may also be regarded as the beginning of that part of the combustion process in which heat is given off. The flames seen over a forest fire or in a fireplace are the burning of distilled gases; combustion products are principally invisible water vapor and carbon dioxide. If combustion is not complete, some of the distilled substances will condense without being burned and remain suspended as very small droplets of liquid or solid over the fire. These condensed substances are the familiar smoke that accompanies most fires. Under certain conditions some of the water vapor may also condense and give the smoke a whitish appearance.

In the third or final phase the charcoal left from the second phase is burned and leaves a small amount of residual ash, which is not a combustion product. If combustion is complete and if the charcoal[1] is mostly carbon, the primary combustion product in this phase will be carbon dioxide because the initial water is driven off in the first two phases. Some carbon monoxide is formed as an intermediate product which in turn burns as a gas to form carbon dioxide. The small blue flames appearing over the coals in a fireplace are carbon monoxide burning. However, if combustion is not complete, small amounts of carbon monoxide remain. In this phase the fuel is burned as a solid, with oxidation taking place on the surface of the charcoal.

Even though the three combustion phases tend to overlap, they can be plainly seen in a moving fire. First is the zone in which leaves and grass blades curl and scorch as they are preheated by the oncoming flames. Next is the flame zone of burning gases.

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[1] The composition of charcoal varies, depending on the conditions under which it is formed. If the distillation temperature is low, 400 to 500° F., the charcoal will contain considerable tar coke. However, in the rapid heating and resultant high temperatures existing in a forest fire, the deposits of secondary products in the charcoal are probably low.

Following the flames is the third but less conspicuous zone of burning charcoal. Unless fuels dry to a considerable depth (that is, unless the Build-up Index is high), this last zone may be almost absent. If this happens the burned-over area will appear black instead of gray, which means that much of the remaining charcoal, as well as some of the underlying fuel, has not completely burned. With the exception of such years as 1947, 1952, and 1955, a blackened burned-over area has been more common than a gray ash-covered area in the Eastern and Southern States.

Heat of combustion

The heat of combustion is heat that makes combustion a chain reaction. Heat supplied to unburned fuel raises its temperature to the point where the fuel, or the gases distilled from the fuel, can react with the oxygen in the atmosphere and in so doing give off more heat. This in turn raises the temperature of adjacent fuel, and thus the chainlike nature of combustion becomes established.

The heat energy released by burning forest fuels is high and does not vary widely between different types of fuels. The tabulation below gives the heats of combustion for a number of substances. These materials and heats were selected from tables in Kent's *Mechanical Engineers Handbook,* 12th edition. Their average is probably a good approximation for forest fuels. Fuels do not ordinarily burn with maximum efficiency, so the actual amount of heat released per pound of fuel in a forest fire will be somewhat less than shown in the tabulation. For a small fire burning in dry fuels with very little smoke, the combustion efficiency might be as high as 80 percent. Large fires burning with dense smoke would be less efficient. Combustion efficiency probably drops somewhat with increasing moisture content.

Substance:	*Heat of combustion per pound, dry (B.t.u.)*
Wood (oak)	8,316
Wood (beech)	8,591
Wood (pine)	9,153
Wood (poplar)	7,834
Pine sawdust	9,347
Spruce sawdust	8,449
Wood shavings	8,248
Pecan shells	8,893
Hemlock bark	8,753
Pitch	15,120
Average (excluding pitch)	8,620

Heats of combustion are given in British thermal units per pound of dry fuel. A B.t.u. is the quantity of heat needed to raise the temperature of 1 pound of water 1° F. For example, the above tabulation shows with the help of a little arithmetic that the burning of 1 pound of an average woody fuel gives off enough heat to raise the temperature of 100 pounds of water about 86° F. To raise the temperature of 100 pounds of water (about 12 gallons) from a temperature of 62° F. to the boiling temperature of 212° F. would require about 1.7 pounds of an average woody fuel if it burned with maximum efficiency. About 1 pound of pitch would accomplish the same result.

The rate of heat release in a forest fire can be visualized by comparing it with a familiar rate, such as that required for house heating. For example, consider a hot, rapidly spreading fire burning with a 20-chain front and with a forward rate of spread of 50 chains per hour. If the fire burns 6 tons of fuel per acre, in 1 hour's time enough fuel would be consumed to heat 30 houses for a year if each house yearly required the equivalent of 10 cords of wood weighing approximately 2 tons per cord. Occasionally there is a fire in the Eastern States with a rate of spread exceeding 5,000 acres per hour. If it burns in a dense, continuous stand of conifers, which might have 12 tons or more of available fuel per acre, such a fire could consume enough fuel in an hour to heat 3,000 houses for a year.

Heat transfer

There are three primary ways in which heat travels or is transferred from one location to another. These are conduction, convection, and radiation. Although dependent on convection, there is a fourth or secondary means of heat transfer in forest fires, which might be described as "mass transport." This is the carrying of embers and firebrands ahead of the fire by convective currents and results in the familiar phenomenon of "spotting."

As a heat-transfer mechanism, conduction is of much greater importance in solids than in liquids and gases. It is the only way heat can be transferred within opaque solids. By means of conduction, heat passes through the bottom of a teakettle or up the handle of a spoon in a cup of hot coffee.

Convection is the transfer of heat by the movement of a gas or liquid. For example, heat is transferred from a hot air furnace into the interior of a house by convection, although the air picks up heat from the furnace by conduction.

Radiation is the type of energy one feels when sitting across the room from a stove or fireplace. It travels in straight lines like light, and it travels with the speed of light.

Most of the preheating of fuels ahead of a flame front is done by radiation. For a fire that occupies a small area and can be thought of as a "point" (such as a small bonfire or a spot fire), the intensity of radiation drops as the square of the distance from the fire increases. For example, only one-fourth as much radiation would be received at 10 feet as at 5 feet from the fire. However, when a fire becomes larger, the radiation intensity does not drop off so rapidly. For a long line of fire, the radiation intensity drops as the distance from the fire increases; that is, one-half as much radiation would be received at 10 feet as at 5 feet. For an extended wall of flame, radiation intensity drops off even more slowly. This tendency for radiation to maintain its intensity in front of a large fire is an important factor in the rapid growth of a fire's energy output.

Convection, with some help from radiation, is the principle means of heat transfer from a ground fire to the crowns of a conifer stand. Hot gases rising upwards dry out the crown canopy above and raise its temperature to the kindling point. Although convection initiates crowning, both convection and radiation preheat the crown canopy ahead of the flames after a crown fire is well established. Convection is also a factor in the preheating of the ground fuels in a surface fire but to a lesser extent than radiation. The effects of both radiation and convection in preheating are considerably increased when a fire spreads upslope, because the flames and hot gases are nearer the fuels. The opposite is true for downslope spread.

Convection and radiation can transfer heat only to the surface of unburned (or burning) fuel. Actually, radiant heat may penetrate a few thousandths of an inch into woody substances and this penetration may be of some significance in the burning of thin fuels, such as grass blades and leaves. However, radiation, like convection, for the most part transfers heat only to the surface of fuel material, and conduction may be considered the only means of heat transfer inside individual pieces of fuel. For this reason conduction is one of the main factors limiting the combustion rate in heavy fuels, such as slash and limbs and logs in blowdown areas. Materials that are poor conductors of heat, such as most forest fuels, ignite more readily than do good conductors, but they burn more slowly. Although the effects of conduction are far less conspicuous than those of radiation and convection, conduction is a very important factor in the combustion process.

Factors affecting the combustion rate

Many factors affect combustion in such complex ways that they are not yet fully understood even for a simple gas or liquid fuel. Solid fuels are even more complex. Even so, there are two rather simple factors that have obvious and definite effects on the combustion rate of woody substances and are of great importance in forest fire suppression. The first of these is the moisture content of the fuel, and the second is fuel size and arrangement.

It is difficult to overestimate the effect of water on the combustion rate and, hence, on fire behavior. Water in a fuel greatly diminishes the preheating rate in the first phase of combustion. Much of the heat is used in raising the temperature of the water and evaporating it from the fuel. The large quantities of resulting water vapor dilute the oxygen in the air and thus interfere with the second or gaseous combustion phase. If the initial fuel moisture is high enough, water vapor may make the mixture so "lean" that the gases will not burn. This dilution of the oxygen in the air also affects the third or carbon-burning phase of combustion. Although data are lacking, it is probable that moisture reduces considerably the heat yield or combustion efficiency. This heat loss would be in addition to that resulting from the water-heating and evaporation requirements.

The effect of size and arrangement of fuel on combustion can be illustrated by the following example. Consider a large pile of dry logs all about 8 inches in diameter. Although somewhat difficult to start, the log pile will burn with a hot fire that may last for 2 or 3 hours. The three primary heat-transfer mechanisms are all at work. Radiation and convection heat the surfaces of the logs, but only conduction can transfer heat inside the individual logs. Since conduction is the slowest of the three heat-transfer mechanisms, it limits the combustion rate in this case. Consider now a similar pile of logs that have been split across their diameters twice, or quartered. Assume that the logs are piled in an overall volume somewhat greater than the first pile, so there will be ample ventilation. This log pile will burn considerably faster than the first one because the combustion rate is less dependent on conduction. The surface area was more than doubled by the splitting, so that convection and radiation are correspondingly increased in the preheating effects. The burning surface is also increased by the same amount.

Assume that the splitting action is continued indefinitely until the logs are in an excelsior state and occupy a volume 30 or 40 times as great as in their original form. Convective and radiative heat transfer will be increased tremendously in the spaces throughout the whole fuel volume, and the combustion rate might be increased to a point where the fuel could be consumed in a few minutes instead of hours.

The effect of fuel arrangement can be visualized if a volume of excelsiorlike fuel, such as that just described, is compressed until it occupies a volume only 4 or 5 times that of the original volume of logs. The total burning surface and radiative conditions remain the same as before compression, but both convective heat exchange and oxygen supply are greatly reduced. There will be a corresponding decrease in fire intensity.

Fuel size and fuel arrangement have their greatest effect on the lower intensity fires and in the initial stages of the buildup of a major fire. When a fire reaches conflagration proportions, the effect on fire behavior of factors such as ignition probability and quantity of firebrand material available for spotting may be greater than the effect of fuel size and arrangement. This point will be discussed in the section on applications to fire behavior.

The fire triangle

The principles of combustion may be summarized in an effective way by means of the fire triangle. This triangle neatly ties together not only the principles of combustion but illustrates their application as well. The three sides of the triangle are FUEL, OXYGEN, and HEAT. In the absence of any one of these three sides, combustion cannot take place. The fire triangle represents the basic link in the chain reaction of combustion (fig. 1). Removing any one or more sides of the triangle breaks or destroys the chain. Weakening any one or more sides weakens the chain and diminishes fire intensity correspondingly. The purpose of all fire suppression efforts is to remove or weaken directly or indirectly one or more sides of the fire triangle. Conversely, all conditions that increase fire intensity operate in such a way as to greatly increase or strengthen the sides of the triangle and, hence, the chain

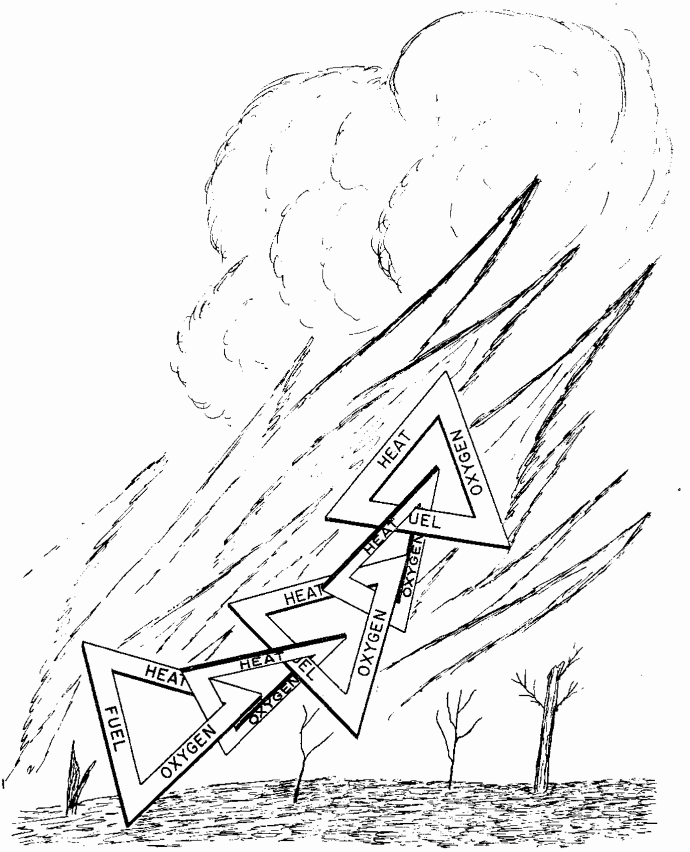

FIGURE 1.—The fire triangle is the basic link in the chain reaction of combustion.

reaction of combustion. In a blowup fire the chain becomes so strong that it cannot be broken by the efforts of man. This means that when blowup conditions exist, the only opportunity to break the chain is by early strong initial attack.

Application to fire behavior

It is more difficult to apply our knowledge of ignition and combustion to the behavior of very high-intensity fires, sometimes referred to as conflagrations or "blowups," than to the behavior of the more frequent low-intensity fires. The ordinary fire behaves for the most part as one would expect from the principles of combustion. In a conflagration or blowup, however, the sides of the fire triangle are greatly strengthened by factors that are absent, or nearly so, in small fires. Although these factors work through the basic combustion principles, they so greatly modify the expected effects of the basic processes that a high-intensity erratic fire cannot be considered as a large-scale model of a low-intensity fire. This is best illustrated by considering the spatial structure of the two types of fires. The height of the significant vertical structure of a low-intensity fire can usually be expressed in tens of feet. This distance is usually small compared to the surface dimensions of the burning area, so that in a physical sense the fire is "thin" or 2-dimensional as far as volume structure is concerned. On the other hand, the significant vertical structure of a well-developed conflagration may extend thousands of feet into the air, and this dimension may at times exceed the surface dimensions of the burning area.

The height that smoke rises above, or in the neighborhood of, a fire is not always a true indicator of the height of the active convection column above a fire. Smoke from a small fire may reach a height of 1,000 feet or more, but active convection may reach only a few percent of this height.[2]

It is the 3-dimensional structure of a large fire that causes it to take on storm characteristics which, in turn, produce behavior phenomena that one could not expect by scaling upwards the behavior of a low-intensity fire. However, this does not mean that scale-model fires, including small fires in the laboratory under controlled conditions, would not be useful in preliminary convection column studies. Probably experimental work on convection column properties should be started first on small scale fires. Such work might give essential fundamental information on the relation between the variables controlling the convection process.

Certain properties of the atmosphere, such as the vertical wind profile and to a lesser extent the vertical temperature profile, appear to be the controlling factors in extreme fire behavior if an extensive area of plentiful dry fuel exists. A discussion of the atmospheric factors is outside the scope of this paper, but it may be well to examine in some detail those phases of the combustion process that permit the atmospheric factors to exert their maximum effect.

Fire behavior is an energy phenomenon and its relation to the combustion process can be understood by the use of four basic fuel factors relating to energy. These are (1) combustion period, (2) critical burn-out time, (3) available fuel energy, and (4) total fuel energy. This last factor is constant, or nearly so, for any given quantity of fuel per acre. The first three are variables which, even for any homogeneous component in a given fuel type, depend on factors such as fuel moisture content and fire intensity. A fifth fuel factor, the quantity of firebrand material available for spotting, is more or less independent of the other four and will be treated separately.

The combustion period may be defined as the time required for a fuel to burn up completely, and depends primarily on fuel size, fuel arrangement, fire intensity, and fuel moisture. It may range from a few seconds for thin grass blades to several hours or longer for logs and heavy limbs. Critical burn-out time is defined as the maximum length of time that a fuel can burn and

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[2] Although it is too involved to discuss in a paper on combustion, the height of the convection zone depends on the rate of heat output of the fire, the wind speed, the vertical wind shear, and the stability of the atmosphere.

still be able to feed its energy into the base of the forward traveling convection column; its magnitude depends primarily on fire intensity or the rate of a fire's energy output. The available fuel energy is that part of the total fuel energy which is fed into the base of the convection column. For fuels with a combustion period equal to or less than the critical burn-out time, the available fuel energy is equal to the total fuel energy. If the combustion period is longer than the critical burn-out time, then the available fuel energy is less than the total fuel energy. Total fuel energy is determined by the quantity of fuel per acre and the combustion efficiency. If the combustion efficiency is assumed to be constant, the terms "available fuel energy" and "total fuel energy" can be replaced by the terms "available fuel" and "total fuel."

An example will illustrate how fire behavior relates to the four preceding quantities. Consider a fire spreading in an area of plentiful heterogeneous fuel, a considerable part of which is in the form of flammable logs and heavy slash and the rest a mixture of smaller material such as twigs, pine needles, and grass. Assume that the critical burn-out time is about 20 minutes. Those fuel components with a combustion period less than 20 minutes will have an available fuel energy equal to their total fuel energy. However, logs and heavy limbs may require several hours to burn out, so their available energy may be comparatively low; they could still be burning after the fire had moved several miles, so would not be affecting the behavior of the fire front.[3] From the standpoint of fire behavior, a crown fire in a dense conifer stand could have more available fuel energy than a fire in an area of heavy logging slash. However, unless large portions of a heterogeneous fuel have very long combustion periods, fuel size and fuel arrangement should not have as much influence on the behavior of major fires as on smaller fires. In a major fire a larger proportion of the heavier fuels take on the characteristics of flash fuels. This is a combined result of the shorter combustion periods and longer critical burn-out times for the high-intensity fires. Nevertheless, fuel size and fuel arrangement contribute heavily to the rate of buildup of fire intensity, especially in the early stages, and are therefore an important part of the fire behavior picture.

Much of the effect of fuel moisture can be interpreted in terms of the four basic fuel factors. Because moisture decreases the combustion rate, it increases the length of the combustion period. This, in turn, means that a smaller fraction of a heterogeneous fuel will have a combustion period less than the critical burn-out time. The available fuel energy and fire intensity will, therefore, drop as fuel moisture increases. For most fires there are some fuel components which do not burn because of their high moisture content; in other words, these components may be regarded as having infinitely long combustion periods.

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[3] Heat sources a considerable distance behind the main flame front could possibly have indirect effects on fire behavior by slightly modifying the structure of the wind field.

An increase in fire intensity can greatly reduce the combustion period for those fuel components with the higher moisture contents. For some components the combustion period might be infinite for a low-intensity fire, but perhaps only a few minutes, or even less, for a high-intensity fire. For example, in the high-intensity Brasstown fire on March 30, 1953, in South Carolina, as well as in other large fires in the Southeast in the last few years, green brush often burned leaving blunt pointed stubs. In a similar manner a reduction of the combustion period from infinity to a few seconds for green conifer needles takes place when a fire crowns.

The fifth fuel factor, the quantity of firebrand material available for spotting, becomes increasingly important as fire intensity increases. Equally important is the relation between surface fuel moisture and the probability of ignition from embers or firebrands dropped from the air. This relation has not as yet been determined experimentally, but ignition probability increases rapidly with decreasing fuel moisture—hence with decreasing relative humidity. We know that the ignition probability for most firebrands is essentially zero when fuel moisture is 25 or 30 percent (on an oven-dry weight basis). We also know that not only ignition probability but combustion rate as well is greatest for oven-dry material. In addition, both of these phenomena in the lower moisture content range appear to be considerably affected by a change of fuel moisture content of only a few percent.

The importance of the relation between fuel moisture and ignition probability in the behavior of large fires can be illustrated by a hypothetical example. Suppose that from the convection column over a large fire, 10,000 embers per square mile per minute are dropping in front of the fire. Suppose that the surface fuel moisture content is such that only 0.1 percent of these firebrands catch and produce spot fires, thus giving only 10 spot fires per square mile. On the other hand, if we assume that the surface fuel moisture is low enough for 5 percent of the embers to catch, then there would be 500 spot fires per square mile. As they burn together, these spot fires would greatly increase the rate of spread and intensity of the main fire. Thus, relative humidity (working through fuel moisture) has a 2-fold effect on rate of spread in certain types of extreme fire behavior. First is the effect on fuel combustion rate and rate of spread of the ordinary flame front. This effect would be present on small and large fires alike. Second is the effect in accelerating rate of spread and fire intensity by increasing the probability of ignition from falling embers. This latter effect would be present only on fires where spotting was abundant. Ignition probability will also depend on other factors, such as the nature of the surface fuel in which firebrands fall and the fraction of the ground area covered by the fuels.

Fuel characteristics that make plentiful and efficient firebrands are not definitely known. The material would have to be light enough to be carried aloft in updrafts, yet capable of burning for several minutes while being carried forward by the upper winds. Decayed punky material, charcoal, bark, clumps of dry duff, and dry moss are probably efficient firebrands. Leaves and grass are more likely to be inefficient firebrands except over short distances.

The initial phases of the blowup phenomenon are directly related to the combustion process and the basic fuel factors. A decreasing fuel moisture means higher combustion rates and shorter combustion periods. There will, therefore, be an increase in the available fuel energy, or available fuel, accompanied by an increase in fire intensity. The increase in fire intensity lengthens the critical burn-out time which means a further increase in available fuel. A cycle of reinforcement is thus established which favors growth of fire intensity. As the intensity increases, the atmospheric factors become increasingly important. It is at this stage that spotting and ignition probability may become dominant fire behavior factors.

By using the basic fuel factors it is possible that a fuel classification method could be developed to classify fuel in terms of expected fire behavior. It would first require a series of burning experiments to measure some of the factors and their response to variables such as moisture content and fire intensity. However, once this was done, the classification system itself might be comparatively simple. Probably its greatest value would be in estimating the conflagration potential of different fuel and cover types for different combinations of weather conditions.

There is an important difference in the energy conversion process for a low-intensity fire and a high-intensity fire. In the "thin" or 2-dimensional fire, most of the energy remains in the form of heat. At the most, such a fire cannot convert more than a few hundredths of one percent of its heat energy into the kinetic energy of motion of the updraft gases and the kinetic energy of the convection column eddies.[4] On the other hand, a major conflagration may convert 5 percent or more of its heat energy into kinetic energy which appears in the form of strong turbulent updrafts, indrafts, convection column eddies, and whirlwinds which can carry burning material aloft. The efficiency of the energy conversion process, and hence the kinetic energy yield, increases rapidly with increasing fire intensity. This is brought about by the mutual reinforcement action in the basic fuel factors plus favorable atmospheric conditions.

In addition to the difference in the energy conversion processes in the two types of fires, there is an enormous difference in rate of energy yield. For example, there were periods in the Buckhead fire in north Florida in March 1956 when the rate of spread probably exceeded 8,000 acres per hour. The rate of energy release from this fire would compare favorably with the rate of energy release from a summer thunderstorm.

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[4] Although a detailed discussion is outside the scope of this paper, energy conversion processes in a fire can be studied by a thermodynamic procedure in which a large fire, like a thunderstorm, can be treated as a heat engine. The efficiency of a heat engine is measured by the fraction of heat or thermal energy that can be converted into the kinetic energy of motion. A 2-dimensional fire has an efficiency as a heat engine that is very nearly zero or, at the most, only a few hundredths of one percent. A major high-intensity fire has an efficiency as a heat engine that may reach 5 percent or more.

Summary

Combustion is basically a chemical chain reaction that can be divided into three separate phases: (1) Preheating and distillation, (2) distillation and the burning of volatile fractions, and (3) the burning of the residual charcoal.

For a forest fuel, ignition is the link between phase 1 and phase 2 of the combustion process.

For most forest fuels the heat of combustion is between 8,000 and 9,000 B.t.u.'s per pound on a dry weight basis.

Heat is transferred by conduction, convection, and radiation. A fourth means of heat transfer might be defined as mass transport and is the familiar phenomenon of spotting, which becomes increasingly important on high-intensity fires.

Fuel moisture has more effect on the ignition and combustion process than any other factor.

Low-intensity fires are essentially 2-dimensional phenomena, and major high-intensity fires 3-dimensional. The third dimension of a high-intensity fire permits the conversion of part of its heat energy into the kinetic energy of motion, which changes the relative significance of the various combustion factors and greatly modifies their expected effects. For this reason a high-intensity fire cannot be regarded as a magnified version of a low-intensity fire.

The relation of fire behavior to the combustion process can be understood by the use of a group of basic fuel factors which are (1) combustion period, (2) critical burn-out time, (3) available fuel energy, (4) total fuel energy, and (5) quantity of material available for spotting. Such a group of factors might be used to classify fuels in terms of expected fire behavior.

If atmospheric conditions are such that one or more strong convection columns can form, the following appear to be the main combustion factors that determine the intensity and rate of spread of a major fire:

1. The quantity of available fuel energy, or available fuel, per acre. The magnitude of this quantity depends on a reinforcing relationship between the basic fuel factors. In turn, this relationship is regulated primarily by fuel size and arrangement, fuel moisture, and the intensity of the fire itself.

2. Quantity of firebrand material per acre available for spotting.

3. Probability of ignition from firebrands dropping ahead of the main burning area. This probability depends on several factors, the most important of which is the prevailing relative humidity determining the surface fuel moisture.

A FUEL-MOISTURE STICK WICKET OF NEW DESIGN FOR USE AT OPEN-TYPE FIRE DANGER STATIONS

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Better equipment design is one way to improve the accuracy of records taken at the hundreds of open-type fire danger stations now in operation in the East and South.

In this connection, the fuel-moisture stick wicket illustrated in figure 1 offers several improvements over the one described in Technical Note 71.[1] These improvements are: (a) the upper projections of the frame support the layers of screen at a uniform 4 inches above the sticks; (b) the lower cross members of the frame rest on the surface of the ground, minimizing penetration, and support the sticks at a uniform 8 inches above the litter and 12 inches above the ground; and (c) the individual slots at each end of the wicket provide positive positioning of the sticks with respect to the screens, litter, and each other.

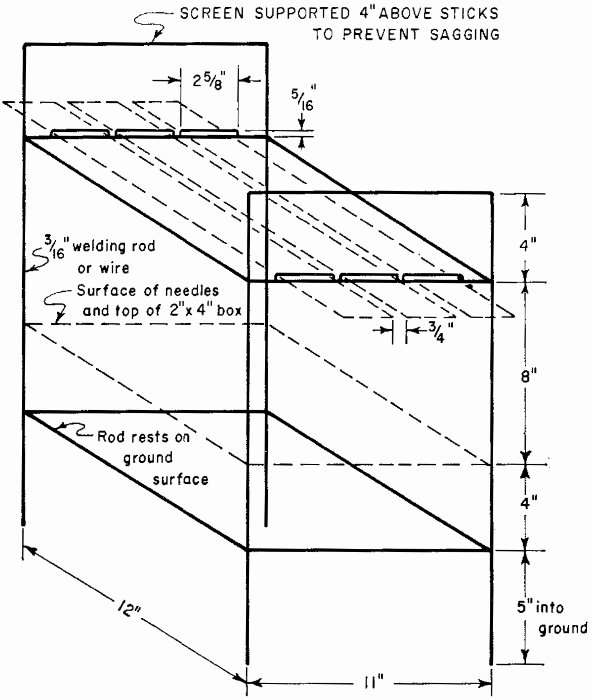

FIGURE 1.

The Southeastern Forest Experiment Station recommends that the new wicket be used as new danger stations are installed or old stations rebuilt.

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[1] Lindenmuth, A. W., Jr., and Keetch, J. J. Open method for measuring fire danger in hardwood forests. U. S. Forest Serv., Southeastern Forest Expt. Sta. Tech. Note 71. March 1949.

FIRE PREVENTION EXHIBIT BY THE SHAWNEE

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Many opportunities to present fire prevention exhibits at fairs and other celebrations are passed up because of the extra work and expense. But at approximately 4-year intervals, we are able to find the time and money to plan and set up an exhibit. To lessen the work entailed in such planning, a description of an exhibit held at the Jonesboro Lincoln-Douglas Homecoming Festival, August 8-11, 1956, may prove helpful.

Fire prevention was the main objective, but prevention cannot be separated from management of forest resources, especially timber and water. An attempt was made to show the economic importance of these resources to southern Illinois and to point out the value of protection to the lumber industry.

The festival was held outdoors; therefore, the kind of material that could be used was limited. Two tents, 14 by 16 feet and 14 by 14 feet, were borrowed from the Nicolet National Forest in Wisconsin. A Smokey Bear costume and photographs for a tree identification quiz were obtained from the Forest Service Regional Office in Milwaukee. Boy Scout Troop 44 of Anna, Ill., accepted duty at the exhibit as participation in a conservation project. In teams of two the Scouts explained the exhibits and contests and guarded the display both day and night.

Believing that people like both to compete and win, we worked up four simple contests and a volume-guessing contest. These games were "bait" to get people thinking about timber and fire. For the winning contestants, local merchants contributed 16 prizes, such as a double-bitted ax, an electric clock, and a card for 12 grease jobs.

More than 90 feet of space along the midway of the festival was used. At the left end of our space a jeep-tanker and tractor-plow unit were parked. Next to the plow unit, but out in front, was the flag on a 15-foot staff. Next, we erected the 14- by 16-foot tent containing: (1) a small 3-foot table with quiz sheets; (2) two wood sections for the age-of-tree contest, one 51 years old from a managed forest and the other 102 years old from an unmanaged forest (people registered and guessed the difference in age of the two sections); (3) a 4-foot showcase containing prizes to be awarded the contest winners; (4) pictures on a 4- by 8-foot panel for the tree identification contest. Outside this tent the nail-driving contest for ladies took place. Each contestant registered and recorded the number of blows necessary to drive a nail into a wood block.

In the second tent we displayed on one side a 4- by 8-foot panel of forester's tools with 3- by 5-inch signs for each tool and on the opposite side a similar panel of fire-fighter's tools. Between the panels a 30- by 70-inch table held a picture panel and sample bulletins. Postal cards were available for ordering bulletins, but no material was handed out. In front and to the right of this tent a tripod held a panel on which hung 2- by 3-foot fire prevention posters. Between the two tents, but out in front, was a forest entrance portal sign.

Next, we decked 16-foot pine logs, cut from an 18-year-old plantation and selected for uniform size of 12-inch butts, to be used in a chopping contest. The chopping contest with seven participants was held on Friday night in the area next to the log deck (fig. 1).

So that visitors might know there was to be such a contest, a sign on a post indicated where and when it would be held and how to register for it. Through a portable public address system the chopping was described; the growing of trees as a crop and how protection contributes to rapid growth was also explained.

To the right of the chopping area was stacked a deck of common native hardwood logs. Visitors seemed interested in the kinds of wood grown in the area and in the marked differences between the species.

At the end of our area we parked a log truck loaded with mixed logs. Contestants registered and guessed the volume in board-feet. Here, too, a sign announced the volume-guessing con-

FIGURE 1.—Chopping contestant attracts interest. Sign holds announcement and lists rules.

test and stated that 19 similar loads were hauled each workday from national-forest land on the Jonesboro District in 1955.

On Saturday night a tie-hewing demonstration was given. Two men each made a tie. Again the public address system was used to describe the life of a tie-hack and to tell something of the history of logging in southern Illinois and the progress made since tie-hacking days.

Hand-printed signs described each display. Such signs also stated the rules of each contest. Smokey Bear appeared every evening, strolled through the crowd, shook hands with the children (fig. 2), greeted parents with remarks on forest management, or drove the tractor forward and back in front of the tents. On Wednesday, Smokey rode the jeep in the parade. Smokey always attracted a crowd. (Construction hint—costume should be air-conditioned.)

FIGURE 2.—Smokey does his part.

There was good press coverage during the festival. Pictures of Smokey and of the chopping contestants appeared in the local papers. The entire layout cost approximately $300 in materials, freight, and time of regular personnel. It was well worth the cost. Everybody had fun, and young and old were educated in fire prevention.

SIMPLIFIED METHOD OF TEACHING USE OF COMPASS

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Teaching the use of the Forest Service compass to a group of prospective smokechasers and lookouts is often a tedious and time-consuming job. The students are invariably confused by the fact that the azimuth circle is reversed on the compass, and the "E" and "W" are interchanged. It is difficult to put across the idea that the needle is actually a stationary point of reference

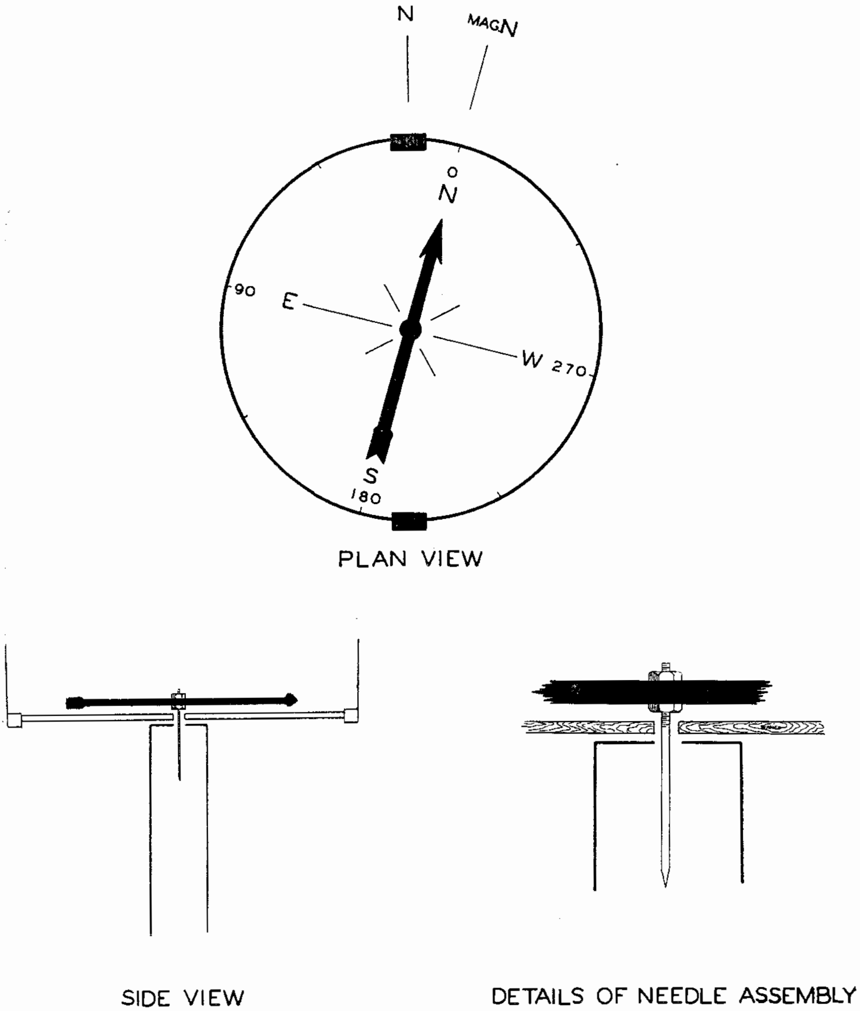

Figure 1.—The "compass" showing alidade positioned for an east declination and details of the needle assesmbly.

when allowed to come to rest, and that its purpose is to show the direction in which the alidade is pointed.

A device found effective in demonstrating the principle of the compass and valuable for group instruction was built by the writer while an assistant ranger on the Kaniksu National Forest. It can be constructed by making a circular dial from a piece of plywood approximately 2 feet in diameter with the azimuth circle printed around the edge in a counterclockwise direction (fig. 1). The size of the dial is not important, but it should be large enough for visibility in group participation. Place alidade bars at the north and south points with the hair to the north as usual and with correction for declination. The alidade can be homemade or salvaged from an old-style bar alidade.

Bore a 3/8-inch hole in the center of the plywood board and mount the board on top of a short post by means of a 1/4-inch iron pin through the hole and into the top of the post. The board should be free to rotate. Rigidly attach a compass "needle" of wood construction on top of the pin by means of two nuts, and orient it toward magnetic north. *The needle must be stationary* and the board allowed to rotate under it.

Now, as the "compass" is turned in any direction, the north end of the needle will point to the azimuth reading appropriate to the direction of the alidade. With this model compass it is simple to explain that the needle is always stationary and merely provides the reading for the alidade. It becomes obvious to the students why the azimuth dial must be reversed because as the compass is turned to the west, for example, the needle, although stationary, appears to move to the east.

This model also makes the significance of the magnetic declination easily understood. When the compass is turned to a position where the needle points to zero, the alidade is oriented to true north.

THREE BIG E'S IN FIRE PREVENTION

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In 1955, incendiarism was responsible for more fires in the United States than any other cause (29.4 percent). Next in number of fires were debris burning (23.2 percent) and smokers (18.1 percent). Sixty-five percent of all fires occurred in the 11 States of the South. In fact, 88.2 percent of all incendiary fires were in the South. To narrow the field further, 6 States—South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana—accounted for 76.3 percent of the Nation's incendiary fires. Analysis of county records shows that in these States the principal incendiary area is in the Coastal Plain counties. In South Carolina, for example, the 21 Coastal Plain counties accounted for 86.4 percent of the 2,600 incendiary fires in the State's 46 counties during fiscal year 1955.

Incendiarism is, therefore, a special fire problem in the six Coastal Plain States. This area, important to the growing of longleaf, slash, and loblolly pines, is one in which prescribed burning is being or can be used for silvicultural purposes, disease control, and fuel reduction.

Although incendiarism is the No. 1 cause, fire prevention educational campaigns have scarcely mentioned the word "incendiary." By poster, platter, pamphlet, and other means the educational efforts have been directed against the second and third causes, debris burning and smoking. The principal lines of appeal have been (1) to urge the exercise of care and (2) to convey an appreciation of the values destroyed or damaged by fires. Both of these appeals are good, but they do little toward fostering an anti-incendiary attitude of the general public who do not set fires. Many people are amazed to learn that any fires are set intentionally. There are those who believe that the answer to incendiarism is law enforcement. The thought is often expressed that although education can reach children and reasonable-minded adults, the incorrigible woods burners must be restrained.

When law enforcement is directed against incendiarism, it encounters problems peculiar to incendiarism as a crime. Usually there is no eye witness to the act and little or no evidence is left for laboratory analysis. Often the best that can be done is a circumstantial case indicating but not proving guilt. Even witnesses to circumstantial evidence are not easily found because they are reluctant to testify. In the incendiary belt, setting fire to other people's woods is not regarded as a crime. Testifying against one's neighbor on such a matter is an unfriendly act. In the face of such an attitude, law enforcement can hardly succeed. The effort to create an anti-incendiary attitude on the part of most of the people and thereby put them on the side of law enforcement has not profited much by the educational campaigns.

Some people think of education and law enforcement as alternative courses, either one of which may be followed. Education and enforcement are not alternatives; they are partners. Prevention of incendiary fires might well borrow the three E's of traffic safety—Education, Enforcement, and Engineering. Each of these is a part of the program which needs all three to succeed.

In following the idea of a program similar to that for highway safety under the three E's, let us consider Enforcement first. Just as the States have adopted adequate highway safety laws, so the States must have adequate forest fire laws. A necessary step would be to class incendiarism as a felony tried in the superior courts, rather than a misdemeanor tried by magistrates. Also, just as the States have created highway patrol forces, they should appoint officers to enforce the fire laws. All fire-control organizations find it manifestly impossible for the same personnel to handle suppression of large numbers of incendiary fires and also to consistently accomplish investigation. The job is even more impossible for those who, in addition, are responsible for heavy programs of resource management.

Fire law enforcement officers should have no responsibility for fire suppression action. The number of officers might be relatively small but provision should be made for their reenforcement during "rush seasons." Assistance in investigations, patrolling special areas, and surveillance of suspects might be given by sheriff's deputies, county police, game wardens, and highway patrolmen.

When not engaged in investigation, fire law enforcement officers should spend most of their time on Education. They must instill in the general non-fire-setting public the idea that setting fire to other people's woodlands is a crime. Then, they must go further and help create a militant anti-incendiary attitude that will lead to aggressive cooperation by the public. Obviously, the educational work necessary to swing neighbors into giving evidence in incendiary cases would have to be directed against incendiarism, not against other causes.

Law enforcement officers should work with individuals and groups. Ready to be used is a vast field of educational material. Also available are the innumerable devices that the educational and advertising experts could create if their talents were directed against incendiarism.

To Education and Enforcement must be added Engineering. There are measures that are neither education nor enforcement but which might be used to combat incendiarism. These measures are mostly physical actions and may well be grouped under engineering. In a recent letter to *American Forests,* Professor H. H. Chapman reminds readers that prescribed burning could play a definite part against incendiarism. There are three principal ways in which prescribed burning could be used.

1. The cause or reason for incendiarism can often be removed by prescribed burning. Be it cattle grazing, turkey hunting, or tick

eradication, the need can probably be served better by a prescribed burn in January than by a wildfire in March. Under some circumstances post-logging slash burning is possible and preferable to the risk of wildfire. Fuel reduction burns in some areas might be increased to once every 3 years.

2. The incendiarists can be denied easy access to roadsides by burning wide firebreaks on both sides of roads. At least, the incendiarists could not flip burning matches from moving cars into the woods. They would be compelled to stop, get out, and cross the burned strip twice—all of which increases their chances of detection and apprehension.

3. An intensive effort should be directed toward breaking up large areas into better patterns of prescribe-burn blocks. The improved layout would make it more difficult for incendiarists to burn large areas in one attempt. The incendiarist who wants a large area burned—for any reason—might be forced to set a dozen fires to do so, each time increasing his chances of being apprehended.

To summarize, it is evident that the prevention of incendiary fires is a matter of changing people's attitudes. The effort to do so may be called Education, but it must be directed against incendiarism, not to other things. Education must be backed by Enforcement, because there *are* incorrigible woods burners. The enforcement officers should also work at education. The success of their enforcement work is directly affected by the success of their educational work. The physical conditions that allow incendiarism to thrive can be greatly improved by prescribed burning, which is here called Engineering. The three measures—Education, Enforcement, and Engineering—might do as much for prevention of incendiary fires as they have done for highway safety.

USE AND EFFECTS OF FIRE IN SOUTHERN FORESTS: ABSTRACTS OF PUBLICATIONS BY THE SOUTHERN AND SOUTHEASTERN FOREST EXPERIMENT STATIONS, 1921-55

David Bruce and Ralph M. Nelson
Southern and Southeastern Forest Experiment Stations

Recent catastrophic forest fires in the South have intensified interest in the damages wrought by fire, and in the possibility of using fire to reduce hazardous accumulations of fuel. The expanded fire prevention campaign that was begun following the Southern Forest Fire Prevention Conference in April 1956 has stimulated a demand for information about fire effects. The steady progress of southern forest management has brought new calls for facts about the silvicultural uses of fire, and about the effects of burning on forest watersheds, game habitat, and forage.

Since their establishment in 1921 the Southern and Southeastern Forest Experiment Stations have issued many publications on these subjects. A great deal of this material is now out of print and accessible only in large libraries. These abstracts should make possible a ready review of the publications of the two Stations, and should guide the selection of references for further reading.

It should be noted that the abstracts do not deal with fire behavior or control. Nor do they include publications by agencies other than the Southern and the Southeastern Forest Experiment Stations. Many of the unreviewed items can be located through the literature cited in K. H. Garren's "Effects of fire on vegetation of the southeastern United States," Bot. Rev. 9: 617-654. Others may be found in some of the publications abstracted herein—specifically the lists of references compiled by Miss Helen Boyd and the bibliography in W. G. Wahlenberg's *Longleaf Pine.*

Abell, M. S.
1932. Much heartrot enters white oaks through fire wounds. U. S. Forest Serv. Forest Worker 8 (6) : 10.

Heartrot caused 40 percent cull of mature white oaks cut in 1930 in Virginia. Rot was traced directly to fire scars in one-third of the trees, and fire probably caused rot in most of the badly rotted and hollow trees. Scars indicated 30 different fires 40 to 236 years before cutting.

Arend, J. L.
1941. Infiltration as affected by the forest floor. Soil Sci. Soc. Amer. Proc. 6: 430-435, illus.

A study in the Missouri Ozarks on seven soil types showed that infiltration was 38 percent lower in adequately stocked oak-hickory stands burned annually than in similar stands protected against fire and grazing for 5 or 6 years. Infiltration was 59 percent lower on heavily grazed unimproved pasture than on protected woods soils, and 33 percent lower on pasture than on annually burned woods soils. Removal of L + F layers did not reduce infiltration so much as annual burning.

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1948. Influences on redcedar distribution in the Ozarks. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 58. [Processed.]

See item immediately below.

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1950. Influence of fire and soil on distribution of eastern redcedar in the Ozarks. Jour. Forestry 48: 129-130.

Redcedar has thin bark and is easily killed by surface fires except on rough stony land where vegetation is too sparse to burn readily. With fire protection, redcedar may become plentiful on better sites.

Barrett, L. I., and Downs, A. A.

1943. Hardwood invasion in pine forests of the Piedmont Plateau. Jour. Agr. Res. 67: 111-128, illus.

In burned shortleaf pine stands, understory climax hardwoods were present in half the amounts found in unburned stands. Understory pine reproduction in burned shortleaf stands increased markedly with advancing age of overstory. Unburned stands showed an opposite trend.

——— Jemison, G. M., and Keetch, J. J.

1941. A method for appraising forest fire damage in southern Appalachian mountain types. Fire Control Notes 5 (2): 101-105. *Also in* U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 44, 13 pp. [Processed.]

The study was based on 150 random ¼-acre plots on 41 burns and 4 large, permanent, burned-over experimental plots in the southern Appalachians. Elements of fire damage considered were: (1) immediate losses resulting from the fire-killing of trees of sawlog size, (2) delayed losses resulting from cull, (3) lowered future sawtimber volumes caused by the killing of trees under saw-log size, (4) reduced growth rate of some surviving trees. A table gives average damage per acre in dollars by fire severity, condition class, forest type, and degree of stocking.

Bickford, C. A.

1942. Cost of controlled burning. Jour. Forestry 40: 973.

The cost of burning depends on the purpose and the care needed to do the job on any particular area.

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1942. The use of fire in the flatwoods of the Southeast. Jour. Forestry 40: 132-133.

Mentions five uses of fire in the Southeast: silviculture, protection, game management, grazing management, and pest control. Discusses protective burning by (1) fuel reduction, and (2) creation of barriers. Suggests analysis of benefits, costs, and damage, and application of all available knowledge to get good results.

——— and Bruce, D.

1948. Fire and longleaf pine reproduction. South. Lumberman 177 (2225): 133-135, illus.

See Bruce, D., and Bickford, C. A., 1950.

——— and Bull, H.

1935. A destructive forest fire and some of its implications. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 46, 4 pp. [Processed.]

Sixty acres of Elk Pasture, near Urania, La., burned on September 17, 1932. Fire had been excluded for 19 years. There were 11 old-growth seed trees and dense stands (900 per acre) of 19-year-old pines—either loblolly

1-10 inches in d. b. h. and 15-50 feet tall or longleaf 1-6 inches in d. b. h. and 10-40 feet tall. Pine needle litter lay 3 inches deep and was also draped on branches and brush. Fire killed all saplings and 96 percent of the seed trees. It is suggested that periodic controlled burning in the longleaf pine type is a more logical practice than either fire exclusion or complete absence of fire protection.

——— and Curry, J. R.
1943. The use of fire in the protection of longleaf and slash pine forests. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 105, 22 pp., illus. [Processed.]

Considers in detail obstacles and benefits of fire use in the Southeast and the steps to be taken: analysis, area selection, examination, mapping, detailed plans, execution, and critical review of results.

——— and Newcomb, L. S.
1947. Prescribed burning in the Florida flatwoods. Fire Control Notes 8 (1) : 17-23, illus.

In the flatwoods, dense slash pine sapling stands unburned for 10 or more years are subject to severe damage from wildfire. Such damage can be avoided by prescribed burning. Steps in executing a prescribed burn are analysis, planning, preparation, burning, and appraisal. Discusses stand size, weather, and execution of burning.

Biswell, H. H., and Lemon, P. C.
1943. Effect of fire upon seed-stalk production of range grasses. Jour. Forestry 41: 844.

Burning greatly increases seedstalk production of native species, especially pineland threeawn and Curtiss dropseed.

——— Foster, J. E., and Southwell, B. L.
1944. Grazing in cutover pine forests of the Southeast. Jour. Forestry 42: 195-198.

From studies near Plymouth, N. C., the authors conclude that there is no place for prescribed burning in the reed forage type. Fires delay the grazing season about 2 weeks, reduce the carrying capacity the following year, and make the reeds more liable to be killed by grazing.

——— Southwell, B. L., Stevenson, J. W., and Shepherd, W. O.
1942. Forest grazing and beef cattle production in the Coastal Plain of Georgia. Georgia Coastal Plain Expt. Sta. Cir. 8, 25 pp., illus.

A survey of 106 cattle-producing farms in 1941 revealed that about 40 percent practiced prescribed burning to insure against devastating fires, to check brush invasion, and to improve grazing. Many attempted to protect reproduction areas and then to burn portions of their forest land every 2 or 3 years.

Boyd, H.
1952. Burning for control of brush and brown spot disease: selected references. U. S. Dept. Agr. Library and South. Forest Expt. Sta., 4 pp. [Processed.]

A list of 44 references dealing with the South.

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1952. Studies of fire damage in hardwood timber: selected references. U. S. Dept. Agr. Library and South. Forest Expt. Sta., 4 pp. [Processed.]

A partly annotated list of 32 references.

Brender, E. V., and Nelson, T. C.

1954. Behavior and control of understory hardwoods after clear cutting a piedmont pine stand. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 44, 17 pp., illus. [Processed.]

Control by cutting lasted little over a year; burning effects lasted 2 years.

Brinkman, K. A., and Swarthout, P. A.

1942. Natural reproduction of pines in east-central Alabama. Ala. Agr. Expt. Sta. Cir. 86, 12 pp., illus.

A survey of pine reproduction in 4 counties indicated that frequent fires had prevented establishment of pine reproduction on about 40 percent of the area. Fire exclusion for 5 years after seedfall appeared necessary to assure adequate reproduction. See Wakeley, P. C., 1944.

Bruce, D.

1947. Thirty-two years of annual burning in longleaf pine. Jour. Forestry 45: 809-814, illus.

The Roberts plots at Urania, La., have demonstrated that longleaf seedlings must be protected from free-ranging woods hogs, and that, under fence, longleaf seedlings on good sites can survive annual winter fires and grow past the size at which they are retarded by such fires. The Roberts plots also show that where fire is excluded and there are loblolly or shortleaf seed trees nearby, these species will invade, and even small numbers of them in dense young longleaf stands of the same age will dominate the area. See Wyman, L., 1922.

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1949. Longleaf regeneration improved by burning. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 60. [Processed.]

Fire before seedfall improves seed catch, survival, and growth of longleaf. See Bruce and Bickford, 1950, for a complete report on the study.

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1949. Seed loss to birds unimportant on fresh burns. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 63. [Processed.] *Also in* Naval Stores Rev. 59 (30) : 5 *and* South. Lumberman 179 (2249) : 221.

In south Mississippi in 1947 and 1948, birds ate very little of the longleaf seed on several small fresh burns having heavy seed supplies.

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1950. It isn't the ashes. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 66. [Processed.] *Also in* Naval Stores Rev. 60 (2) : 4.

Rapid early growth of longleaf seedlings on spots where pine logs have recently burned seems due to the fact that fire killed the grass roots rather than to any fertilizing or mulching effect of the wood ashes.

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1951. Factors affecting fuel weight. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 73. [Processed.] *Also in* South. Lumberman 183 (2297) : 206.

See Bruce, D., 1951, *Fuel weights on the Osceola National Forest.*

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1951. Fire resistance of longleaf pine seedlings. Jour. Forestry 49: 739-740.

Longleaf seedlings germinating on fresh burns survived fires well when a year old because the roughs were thin; seedlings that had germinated on 1-year and older roughs suffered severe mortality. Size and vigor of seedlings are important in estimating probable survival. When longleaf seedling stands are large enough to start height growth, fires kill few seedlings that would not have died from other causes in 2 or 3 years.

———— 1951. Fire, site, and longleaf height growth. Jour. Forestry 49: 25-28, illus.

Two similar studies of fire effects on longleaf seedlings in Mississippi and Florida indicated that local differences in soil had more influence on height growth than did fire. In Florida, the unburned seedlings grew best; and the more frequent and more severe the fires, the poorer the survival and growth. On a better site in Mississippi, growth was improved by the use of light fires (both winter and summer) when seedlings were 4 years from seed.

———— 1951. Fuel weights on the Osceola National Forest. Fire Control Notes 12 (3): 20-23, illus.

Density of stand, age of rough, and understory brush affected fuel weight in north Florida. Dense stands had 4 tons more fuel than open stands. Ten- to 15-year roughs had about 5½ tons more fuel than 1-year roughs. There were about 2 tons more fuel where gallberry or palmetto plants were present than where they were absent. Fuel weights per acre ranged from 1½ tons on open 1-year roughs with no brush to 22 tons under dense stands having 10-year or older roughs with palmetto understory.

———— 1952. Fire pruning of slash pine doesn't pay. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 78. [Processed.] *Also in* Fire Control Notes 13 (2): 17.

A small gain in pruning 8-year-old slash on an upland site by severe fire was offset by loss of one-half year's growth.

———— 1954. Mortality of longleaf pine seedlings after a winter fire. Jour. Forestry 52: 442-443, illus.

Brown-spot defoliation may be more important than height of longleaf seedlings in determining how many ½- to 4-foot seedlings will be killed by fire. In a light winter fire maximum mortality was in seedlings 1 to 1½ feet tall. All size classes of seedlings over two-thirds defoliated by the brown-spot needle blight a year before the fire suffered more than 38-percent mortality. Brown-spot reduced fire resistance of seedlings ½ to 1½ feet tall more than of seedlings less than ½ foot tall. The best way to insure low mortality is to keep seedlings healthy by burning before many of them are more than one-third defoliated by the disease.

———— 1955. Longleaf led the way. La. State Univ., School of Forestry, Fourth Ann. Forestry Symposium Proc., pp. 79-85. [Processed.]

Frequent fires for thousands of years resulted in almost pure stands of virgin longleaf pine on the Lower Coastal Plain. The sandy, gently rolling soils were not damaged by fire, frequent fires kept the fuel light, and longleaf was the most fire-resistant species present. Since logging of the virgin stands, it has been found that seedbed preparation and brown-spot control are necessary to get second-growth longleaf stands. Use of fire is the most economical means of accomplishing these purposes, and also will result in lower fuel hazard, reduced competition, and improved spring cattle grazing. Primary purposes for use of fire in other southern pine types are for understory shrub-hardwood control and seedbed preparation. Outside of the longleaf type, soils are more susceptible to erosion when the vegetation is burned off, and the more hilly country (as well as the less uniform fuels) makes prescribed fires harder to control.

——— and Bickford, C. A.

1950. Use of fire in natural regeneration of longleaf pine. Jour. Forestry 48: 114-117, illus.

A test begun in 1933 on a 1,000-acre fenced tract in central Louisiana showed that prescribed use of fire improves seed catch, increases survival, and stimulates height growth of longleaf pine. Survival in a dry first year was 22 percent on fresh burns and 1-year roughs and only 10 percent on 2-year and older roughs. More of the yearling seedlings survived the next 6 years on these fresh burns and 1-year roughs, and the survivors made better height growth. Prescribed burning once or twice in the 6-year period after seedlings were a year old resulted in better survival and growth than no burning or annual burning. See Bickford, C. A., and Bruce, D., 1948; Bruce, D., 1949, *Longleaf Regeneration Improved by Burning.*

Byram, G. M.

1948. Vegetation temperature and fire damage in the southern pines. Fire Control Notes 9 (4): 34-36, illus.

Theoretical curves show the relative fire intensities that longleaf, slash, and loblolly pine should tolerate at different temperatures. At a temperature just above freezing these pines should tolerate a fire more than twice as intense as they would on a warm day when the vegetation temperature is 95°.

——— and Nelson, R. M.

1952. Lethal temperatures and fire injury. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 1, 2 pp., illus. [Processed.] *Also in* Naval Stores Rev. 62 (20): 18.

The lethal effects of a fire of given intensity vary inversely as the difference between the lethal temperature and initial vegetation temperature. For equal intensities a backfire would scorch a tree crown higher than a headfire. But headfires actually scorch to considerably greater heights because their intensity is almost always several times as great as that of a backfire.

Campbell, R. S.

1954. Fire in relation to forest grazing. Unasylva 8 (4): 154-158, illus.

Cites use of fire in forest land management in southeastern United States as an example of relation between fire use and grazing. Points out that grazing may reduce fire hazard by removing as much as 44 percent of the herbage and by compacting fuel, and that cattle may make seedbed and fertilized firebreaks relatively fireproof by close grazing. See Campbell and Cassady, 1951; Harper, 1944; Heyward and Barnette, 1934; Heyward and Tissot, 1936; Wahlenberg, Greene, and Reed, 1939.

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1955. Vegetational changes and management in the cutover longleaf pine-slash pine area of the Gulf Coast. Ecol. 36: 29-34, illus.

Secondary plant succession in the longleaf-slash pine belt of the Gulf Coastal Plain is influenced by timber cutting, burning, and grazing. The damaging effects of uncontrolled annual burning are in part alleviated by substituting prescribed burning in managed stands, which is useful in reproducing and growing longleaf and slash pines and in improving grazing. Hogs and sheep are serious threats to the early survival and growth of the pines, but cattle usually do little harm. The scrubby hardwoods and underbrush that naturally develop under selective cutting of the pine or under protection from fire are a serious problem. Increasing intensity of land management for timber growing and range grazing may cause deterioration of soil fertility and physical condition.

——— and Cassady, J. T.

1951. Grazing values for cattle on pine forest ranges in Louisiana. La. Agr. Expt. Sta. Bul. 452, 31 pp., illus.

Nutritive value was not greatly affected by burning, but fire removed the rough of grass and weeds and made the fresh forage more easily available

for grazing. Prescribed burning should be done only under supervision and advice of a forester, and only when and where the timber stand will benefit.

——— Epps, E. A., Jr., Moreland, C. C., Farr, J. L., and Bonner, F.
1954. Nutritive values of native plants on forest range in central Louisiana. La. Agr. Expt. Sta. Bul. 488, 18 pp., illus.

Burning removes old growth and stimulates succulent new growth high in crude protein and phosphorus. The greatest difference between burned and unburned range was in spring (March-May), when most grasses are in the young-leaf stage. At other seasons, differences were small and inconsistent. In addition to increasing protein and phosphorus, burning makes it possible for the grazing animal to take new growth, unmixed with less nutritious older grass. Repeated burning may reduce amount of forage produced.

Cassady, J. T.
1953. Burning may reduce grass production. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 85. [Processed.]

In central Louisiana, burning for 2 consecutive years reduced grass production during the second year by 42 percent (as compared with an area burned the first year only).

——— Hopkins, W., and Whitaker, L. B.
1955. Cattle grazing damage to pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 141, 14 pp., illus. [Processed.]

Describes eight instances of grazing damage to pine seedlings in central Louisiana. Among other things, points out that fire may lead to heavy damage because cattle tend to concentrate on recent burns.

Chaiken, L. E.
1949. The behavior and control of understory hardwoods in loblolly pine stands. U. S. Forest Serv. Southeast. Forest Expt. Sta. Tech. Note 72, 27 pp., illus. [Processed.]

The use of pre- and post-logging fires for pine regeneration and hardwood control. Discusses season of burning, types and frequency of fires, and cost of prescribed burning.

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1950. This hardwood problem. Forest Farmer 9 (6): 8-9, illus.

The pros and cons of hardwood control by prescribed fire versus other methods.

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1952. Control inferior tree species. South. Lumberman 184 (2306): 38-39. *Also in* The Unit, News Letter 41, pp. 33-36. [South. Pulpwood Conserv. Assoc.]

Points out some of the uses and limitations of prescribed fire to retard the development of competing hardwoods in southern pine stands.

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1952. Annual summer fires kill hardwood root stocks. U. S. Forest Serv. Southeast. Forest Expt. Sta. Research Note 19, 1 p. [Processed.]

Summer fires are more effective than winter fires in killing rootstocks and in reducing size and vigor of sprouts from surviving rootstocks.

———— 1952. Extent of loss of loblolly pine seed in winter fires. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 21, 2 pp. [Processed.] *Also in* South. Lumberman 185 (2321) : 260.

On areas burned after the bulk of a year's pine seed crop has fallen, seedlings arise either from seed that lodges in sheltered and protected spots or from seed disseminated after a fire. It is unlikely that enough seed will fall during February or March to restock an area adequately.

———— and LeGrande, W. P., Jr.
1949. When to burn for seedbed preparation. Forest Farmer 8 (11) : 4.

If timed to take advantage of heavy seed crops, fire can create a favorable ground surface for loblolly pine seed germination. Peak of loblolly seed fall occurs during the first part of November. The best season to burn therefore is perhaps September or October.

Cooper, R. W.
1951. Release of sand pine seed after a fire. Jour. Forestry 49: 331-332, illus. *Also in* South. Lumber Jour. 55 (8) : 56, 58, 60, illus.

Abundant seedfall, resulting from a wildfire in February on the Ocala National Forest in Florida, gave rise to adequate reproduction. By May, however, the entire crop had been wiped out, presumably by drought and high surface temperatures.

———— 1952. Regeneration problems in sand pine. South. Lumberman 184 (2303) : 43-44. illus.

Sand pine grows in dense, even-aged, pure stands as a direct result of past fires. Cones are very persistent and seldom open on standing trees. Wild fires open the cones and bring about release of large quantities of seed followed by dense reproduction. However, the old stand having been destroyed, this method has little practical value for the forester.

———— 1953. Prescribed burning to regenerate sand pine. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 22, 1 p. [Processed.] *Also in* South. Lumberman 186 (2331) : 50.

Early response to prescribed burning indicates that more information is needed on the time of year to burn, on the interval between cutting and burning, and on the number of seed trees.

Craig, R. B., Marburg, T. F., and Hayes, G. L.
1946. Fire losses and justifiable protection costs in the Coastal Plain region of South Carolina. U. S. Forest Serv. Southeast. Forest Expt. Sta., 46 pp. [Processed.]

See item immediately below for type of analysis made in this area.

———— Frank, B., Hayes, G. L., and Jemison, G. M.
1945. Fire losses and justifiable protection costs in southern Piedmont of Virginia. U. S. Forest Serv. Appalachian Forest Expt. Sta., 27 pp., illus. [Processed.]

Analyzes the justifiable expenditure for fire control in seven counties of the southern Piedmont of Virginia by balancing all costs for prevention, presuppression, and suppression against losses to all resource values at stake. Determines the point at which the sum of costs and losses is minimized. The cost of this least-cost-plus-loss point is the economic limit of justifiable expenditure for fire control under existing conditions and present type of fire control.

——— Frank, B., Hayes, G. L., and Marburg, T. F.
1946. Fire losses and justifiable protection costs in the southwestern coal section of Virginia. U. S. Forest Serv. Southeast. Forest Expt. Sta., 45 pp. [Processed.]

Same type of analysis as described in item immediately above.

Davis, V. B.
1955. Don't keep longleaf seed trees too long! U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 98. [Processed.]

Longleaf seed trees not only keep longleaf seedlings small by competition, but their needles increase the amount of fuel. Near seed trees, a fire killed 50 percent of the seedlings 0.2 inch in diameter at the root collar and 10 percent of those that were 0.3 inch. Away from heavy needle fall, mortality in these size classes was 18 percent and 7 percent.

Demmon, E. L.
1926. Fire damage in virgin pine stands of the South. Lumber Trade Jour. 90 (6) : 19-20. *Also in* South. Lumberman 124 (1615) : 47.

In 1924, 24,000,000 acres burned in nine southern States. This was 84 percent of the total in burned area in the United States. Although damage is not confined to mature trees, a large percentage of them bear the scars of repeated fires for over 100 years.

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1928. What the forest fires of 1927 did to the pines on Georgia cutover lands. Naval Stores Rev. 38 (35) : 14-15.

Severe burns in the spring of 1927, when ponds in southern Georgia were dry, killed many trees over 8 inches d. b. h. On two large fires, 32 percent of round longleaf were killed and 56 percent of the turpentined longleaf. Slash pine suffered higher mortality because it grew in previously unburned ponds: 48 percent for round trees, and 78 percent for turpentined. In other areas, slash seedling and sapling mortality averaged 85 percent within 100 yards of ponds and less than 33 percent farther away. Fire resistance increased rapidly with size. Practically all slash less than 7 feet were killed, about 50 percent of the 10-foot saplings, and less than one-third of the 14-foot class. Frequent fires kill young slash before they are fire resistant and keep many areas bare of reproduction.

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1929. Fires and forest growth. Amer. Forests and Forest Life 35: 273-276, illus.

Cites many instances of fire damage to southern forests.

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1931. Fires in the South. U. S. Forest Serv., Serv. Bul. 15 (11) : 2-3.

Cites instances of severe damage from fires in spring of 1927 in south Georgia. Mentions study of fire scars in virgin pine stands.

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1932. Fire in the southern pine forests. U. S. Forest Serv. South. Forest Expt. Sta., 6 pp. [Processed.]

A general resumé of knowledge and opinion regarding the relation of fire to the growing of pine. Points out that each forest stand is different and no general statement will fit all conditions. Fires have been frequent and have caused much damage. Longleaf is the most fire-resistant southern pine. Fire can be used in longleaf stands to prepare seedbeds, control brown spot, and reduce fuel hazard.

———— 1935. The silvicultural aspects of the forest-fire problem in the longleaf pine region. Jour. Forestry 33: 323-331.

There are more fires in the longleaf belt (50-60 million acres) than elsewhere in the South, and more in the South than elsewhere in the United States, but these fires do not cause as much damage per acre as do fires in other regions. The frequency of the fires is partly due to the high flammability of the surface vegetation in winter. Controlled burning is used for seedbed preparation, brown-spot control, reducing competition, reducing fire hazard, improving pasture, and bettering habitat conditions for game. To grow longleaf, mastery of fire is essential. Such mastery requires, among other things, more knowledge of fire causes, behavior, effects, and uses.

———— 1942. Periodicity of forest fires in the South. South. Lumberman 165 (2081) : 220-222, illus.

Frequent fires in the South are not so spectacular as fires in other regions, but they exact their toll by scarring and killing trees. Fire causes are discussed and records of numbers of fire and area burned are presented. Most fires occur from October through April, with the major peak in March. Only half of the forest area in the South is now under organized fire protection.

Derr, H. J., and Cossitt, F. M.

1955. Longleaf pine direct seeding. Jour. Forestry 53: 243-246, illus.

Longleaf pine direct seeding should be done in late October or November on light roughs or disked strips. Light roughs are prepared by burning 5 or 6 months before seeding. Fresh burns may attract birds even where the burned area is adjacent to the seeded area. Grass roughs older than one year obstruct germination and may harbor a high rodent population. Disking on poor dry sites may reduce seedling losses if the first summer is dry, and should be done about 3 months before seeding to let the soil settle. Protection against hogs, grazing animals, birds, ants, and other animals that eat seed or damage young seedlings may be necessary.

———— and Mann, W. F., Jr.

1954. Future forests by direct seeding. Forests and People 4 (4) : 22-23, 38-39, illus.

A one-year grass rough is usually the best seedbed for longleaf pine. On dry sandy sites, however, disked strips through a one-year rough may improve survival.

Eldredge, I. F.

1935. Administrative problems in fire control in the longleaf-slash pine region of the South. Jour. Forestry 33: 342-346.

Forest management will remain a gamble until the forest fire problem of the South is solved. Although much of the area burned shows little damage, there are many areas of vulnerable young slash pine developed by 6 or 8 years of protection in which fire control is extremely difficult in dry years. Controlled fire is needed in the reproduction of longleaf pine, and may have a place in hazard reduction. Advocacy of controlled burning will be very difficult for public agencies responsible for fire protection.

Elliott, F. A., and Pomeroy, K. B.

1948. Artificial regeneration of loblolly pine on a prescribed burn. Jour. Forestry 46: 296-298.

Effects and costs of a single prescribed fire in loblolly pine in the Coastal Plain of Virginia.

Ferguson, E. R.

1955. Fire-scorched trees—will they live or die? La. State Univ., School of Forestry, Fourth Ann. Forestry Symposium Proc., pp. 102-112, illus.

In east Texas in 1954, 975 sample trees, mostly loblolly and shortleaf with some longleaf, were tagged on severe burns. Damage to crowns and trunks was classified soon after the fire, and trees were checked at the end of the growing season to see if they lived or died. Trees most likely to die were those with all foliage consumed; those with all foliage scorched plus very severe bark burn or extensive bark burn; those with both extensive and severe bark burn; and those in summer fires that had either complete foliage scorch, extensive bark burn, or very severe bark burn. Shortleaf pines, suppressed trees, and trees under 10 inches d. b. h. were poorer risks than loblolly or longleaf, trees in upper crown classes, or trees over 10 inches d. b. h.

——— and Stephenson, G. K.

1953. Fire effects studied. South. Lumberman 187 (2345): 244, illus. *Also in* Fire Control Notes 15 (3): 30-32, illus.

In east Texas, fire may be used to kill young hardwoods and to improve seedbeds for pine. Studies are under way to measure effects of these fires on soils and watershed conditions and on hardwoods and pines.

——— and Stephenson, G. K.

1955. Pine regeneration problems in east Texas: A project analysis. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 144, 72 pp., illus. [Processed.]

Reviews literature dealing with prescribed burning for seedbed preparation and for improving seedling survival. Suggests additional work to define the most effective burning conditions, to measure effects of reduced root competition on soil moisture, and to measure possible effects on watershed values.

Forbes, R. D.

1924. Fire in loblolly pine, Urania, Louisiana. U. S. Forest Serv., Serv. Bul. 8 (17): 5-6.

Three sets of plots were established for observing effects of burning on loblolly pine. In a sapling and pole stand, a spring fire in 1923 weakened trees, and bark beetles (*Ips* sp.) attacked them. A summer fire was lighter because the fuel was moist. Fall was too wet for any burning.

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1925. White smoke. Amer. Forests and Forest Life 31: 458-462, illus.

Fire prevention depends on knowledge of fire causes. In the Southeast and possibly in California, a major cause of fire is burning to "improve" grazing conditions. In the Southeast, it seems possible in the future to grow more and better cattle and timber by confining cattle to pastures having about ¼ to ½ the present open range area.

Forsling, C. L.

1936. Forest fires in Central Europe. Farmers' Federation News 16 (7): 18.

Fire causes relatively little damage in the forests of Central Europe as compared to the United States. Europeans have a greater appreciation of the social and economic value of forest land and accordingly are more careful with fire.

Frothingham, E. H.

1931. Timber growing and logging practice in the southern Appalachian region. U. S. Dept. Agr. Tech. Bul. 250, 93 pp., illus.

General information on fire effects in hardwood stands.

Gemmer, E. W., Maki, T. E., and Chapman, R. A.

1940. Ecological aspects of longleaf pine regeneration in south Mississippi. Ecol. 21: 75-86, illus.

Field tests showed that longleaf seed must be protected against birds and mice. Wire tubes, mulches, and drill seeding gave promising results. Greenhouse tests showed best germination on mineral soil and light, well-watered humus. Heavy ash deposits were detrimental. Hardness of surface soil did not affect germination but did affect penetration by radicles. A field trial indicated poorer catch on burned and cultivated seedbeds than on 3-year grass rough because of loss of seed to birds on exposed seedbeds.

Gruschow, G. F.

1952. Effect of winter burning on growth of slash pine in the flatwoods. Jour. Forestry 50: 515-517, illus. *Also in* South. Lumberman 183 (2297): 260, 262, 264, illus. 1951.

Presents some evidence that headfires should not be prescribed where slash pine is a desired stand component and where slash pine reproduction is becoming established. Under favorable conditions, prescribed burning with a backfire results in negligible loss of growth in stands over approximately 12 feet tall. Headfires reduce both height and diameter growth.

Haig, I. T.

1938. Fire in modern forest management. Jour. Forestry 36: 1045-1049.

Discusses the use of fire for numerous management purposes in several regions. Questions whether foresters are taking a sound or desirable position by citing fire as a soil destroyer where only direct action on fertility is concerned.

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1950. Solving the riddle of low grade hardwoods. Amer. Forests 56 (2): 28-30, 40-41, illus.

Under even-aged management, proper use of prescribed fire promises to be one of the cheapest and most effective ways of controlling hardwood invasion.

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1950. The control of undesirable hardwoods in southern forests. Forest Farmer 9 (11): 9, 11, 14, illus.

General discussion on the use of fire for hardwood control.

Halls, L. K.

1954. Low-cost range improvement pays in the Southeast. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 54, 2 pp. [Processed.]

Spring broadcasting of carpetgrass and lespedeza seed on cutover slash pine forest land, burned the previous fall, increased the annual return from grazing three-fold, from $2.10 to $6.14 per acre.

——— and Suman, R. F.

1954. Improved forage under southern pines. Jour. Forestry 52: 848-851, illus.

Good stands of improved forage species such as Louisiana white clover, carpetgrass, and Dallas grass can be established without tillage in longleaf-slash pine forests following litter removal by burning.

——— Southwell, B. L., and Knox, F. E.

1952. Burning and grazing in coastal plain forests. Ga. Coastal Plain Expt. Sta., Univ. Ga. Bul. 51, 33 pp., illus.

Results of a 7-year study of vegetation and cattle responses to burning frequency (1-, 2-, and 3-year intervals vs. no burning) in longleaf-slash pine

forests of Georgia; ecological trends and chemical composition of forage species, diet and weight gains of young cattle, fuel accumulation, and tree reproduction. General relationship between amount of tree canopy and herbaceous understory is also discussed.

Harper, V. L.
1937. Fire research in the lower South. Fire Control Notes 1 (5): 229-237.

Tremendous areas are burned by wildfire each year in the South, and at the same time controlled burning is being used in forest management. The acute fire problems appear to be: (1) better fire protection methods; (2) a method of evaluating the effects of fire; and (3) controlled-burning technique.

———
1944. Effects of fire on gum yields of longleaf and slash pines. U. S. Dept. Agr. Cir. 710, 42 pp., illus.

Surface fires that caused no defoliation were followed by slight increases (4 percent) in gum yield in the year following fire but had no effect on second-year yields. Crown defoliation reduced gum yields; the greater the defoliation the greater the loss. Turpentining probably should be deferred at least 1 year after moderate crown damage.

Harrar, E. S.
1954. Defects in hardwood veneer logs: their frequency and importance. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 39, 45 pp., illus. [Processed.]

Briefly mentions decay following fire.

Harrington, T. A., and Stephenson, G. K.
1955. Repeat burns reduce small stems in Texas Big Thicket. Jour. Forestry 53: 847.

In the Big Thicket of southeast Texas, areas were burned once in the spring of 1948, twice in the springs of 1948 and 1951, and three times in the springs of 1948, 1951, and 1952. There was a sparse loblolly-shortleaf pine sawtimber overstory beneath which hardwoods, shrubs, and vines precluded pine regeneration. Burning was done when wind and fuel permitted complete and rapid spread with negligible damage to the overstory. Number of shrubs and hardwoods from ½ to 3½ inches counted in November 1954: unburned, 2,812 per acre; one burn, 1,916; two burns, 1,479; and three burns, 520 per acre. The average reduction of 731 stems for each added fire reflects both kill by reburning and the longer period for reestablishment of small stems since the first and second burns. Repeated burns seem needed to reduce hardwood understories in the Big Thicket type.

Hepting, G. H.
1935. Decay following fire in young Mississippi delta hardwoods. U. S. Dept. Agr. Tech. Bul. 494, 32 pp., illus.

The greatest losses from decay in young Delta hardwoods result from fire-scarring. Decay spreads upward from fire wounds most rapidly in the oaks (2.3 inches per year), and then in ash, sweetgum, hackberry, and persimmon. Relations were established between rate of decay and tree age and diameter, wound size, and fungus causing the decay. Many insects, chiefly ants and termites, inhabited the decayed wood behind fire scars, but there was little insect invasion of sound wood from fire scars.

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1941. Prediction of cull following fire in Appalachian oaks. Jour. Agr. Res. 62: 109-120, illus.

An intensive study of fire-scar butt rot on a large number of commercial logging operations provided a mechanism by which it is possible to predict, for fire scars of different sizes, what the volume of decay will be for any given number of years after a fire. Sixty years after burning, wounds 5 inches wide resulted in only 5 board-feet of cull, while wounds 25 inches wide resulted in 160 board-feet of cull.

——— and Blaisdell, D.
1936. A protective zone in red gum fire scars. Phytopath. 26: 62-67.

Describes a gum-filled zone on the face of red gum fire scars that serves as a protection against decay.

——— and Chapman, A. D.
1938. Losses from heart rot in two shortleaf and loblolly pine stands. Jour. Forestry 36: 1193-1201, illus.

Basal wounds, chiefly those caused by fire, were by far the most common means of entrance for *Polyporus schweinitzii*. Amount of cull from this fungus is reported.

——— and Hedgcock, G. G.
1935. Relation between butt rot and fire in some eastern hardwoods. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 14, 2 pp. [Processed.]

Results of a study of more than 5,000 eastern hardwoods are presented in a table showing percent of trees by species having fire wounds and the cull percent due to butt rot.

——— and Hedgcock, G. G.
1935. Relation of cull percent to tree diameter and to percentage of trees with basal wounds in some eastern hardwoods. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 16, 4 pp., illus. [Processed.]

Presents graphs showing the relation of cull percent to tree diameter and percent of trees with basal wounds.

——— and Hedgcock, G. G.
1937. Decay in merchantable oak, yellow poplar, and basswood in the Appalachian region. U. S. Dept. Agr. Tech. Bul. 570, 30 pp., illus.

An analysis of the amount of cull in oaks, yellow-poplar, and basswood throughout the Appalachian region, based on studies from 19 logging operations. Percentages of cull are given for all species by areas, and this cull is related to tree diameter, age, fire, and other factors. Butt rot and top rot are analyzed separately.

——— and Kimmey, J. W.
1949. Heart rot. U. S. Dept. Agr. Yearbook 1949, pp. 462-465.

Many timber stands have been repeatedly burned, so that practically all old trees have scars at their butts. Fungi entering through the scars account for a large proportion of the heart rot in older stands.

Heyward, F. D.
1934. Comments on the effect of fire on feeding roots of pine. Naval Stores Rev. 44 (19) : 4.

The head of the April 13 fire at Cogdell, Ga., killed pine feeding roots to a depth of one inch. Usually damaging heat from surface fire penetrates no more than ¼ inch in dry mineral soils and even less in moist soils. When ponds or swamps dry out, all dry organic matter may be consumed, sometimes to depths of several feet. Both longleaf and slash pine develop new feeding roots in the top few inches of soil soon after fire. Pine roots may be found to be as resistant to fire damage as above-ground portions of the trees.

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1936. Soil changes associated with forest fires in the longleaf pine region of the South. Amer. Soil Survey Assoc. Bul. 17 (Proc. 16th Annual Meeting), pp. 41-42.

Soils protected from fires were more penetrable and porous than soils subjected to frequent fires. Protected sandy soils had a higher hygroscopic

coefficient and higher wilting percent than burned sandy soils, but in sandy loams similar differences were not found. Burned soils had higher loss on ignition, more replaceable calcium, higher pH, and higher total nitrogen than unburned soils. No evidence indicated either severe soil degradation or improvement from periodic fires. Soil is rarely heated above ignition point of organic matter deeper than ¼ inch. Most differences in soils are attributed to differences in ground cover.

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1937. The effect of frequent fires on profile development of longleaf pine forest soils. Jour. Forestry 35: 23-27, illus.

Because of frequent fires, most longleaf pine forest soil resembles a grassland soil more than a typical forest soil. The ground cover is mainly hardy perennial grass and the A_1 horizon is dense and lacks active soil fauna. Where fire is excluded, a forest floor 2 to 3½ inches thick is formed, smothering grasses; and soil fauna renders A_1 horizon more penetrable and porous. Heavier soils may exhibit crumb structure.

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1938. Soil temperatures during forest fires in the longleaf pine region. Jour. Forestry 36: 478-491, illus.

Soil temperatures during fires in natural fuels in longleaf pine forests at depths of ⅛ to ¼ inch generally ranged from 150° to 175° F. for periods of 2 to 4 minutes, with a maximum of 274°. At ½-inch depth the maximum observed was 195°, but in 15 of 65 records there was no rise in temperature.

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1939. Some moisture relationships of soils from burned and unburned longleaf pine forests. Soil Sci. 47: 313-327, illus.

Soil samples from four paired burned and unburned pine stands in northeast Florida showed that in about half of 84 determinations at 0- to 2-inch depth, 4- to 6-inch depth, and 8- to 10-inch depth, the unburned soils were significantly moister than the burned. None of these paired samples (taken between July 1936 and July 1937) showed that burned soils were significantly moister than unburned. Differences in moisture retention determined in the laboratory were neither large nor consistent. On areas protected from fire, there was a continuous loose mulch of dead plant material, whereas burned areas had sparser ground cover consisting of young, vigorous plants. Differences in moisture utilization and mulching effects are probably responsible for the higher observed moisture in unburned soils.

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1939. The relation of fire to stand composition of longleaf pine forests. Ecol. 20: 287-304, illus.

In 51 long-unburned forests of longleaf and slash pine from South Carolina to Louisiana, there was a consistently greater number of hardwoods than in nearby frequently burned stands. Where no fires had hindered their growth, hardwoods occupied a considerable part of the dominant crown canopy. When unwanted hardwoods are not over 2 inches in diameter, controlled fires will keep them in check.

——— and Barnette, R. M.

1934. Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Fla. Agr. Expt. Sta. Bul. 265, 39 pp., illus.

Soils subjected to frequent fires were less acid, and had higher percentages of replaceable calcium and total nitrogen. They also appeared to have more organic matter, judged by loss on ignition. These differences were observed in the top 4 to 6 inches of soil. Unburned areas were covered with pine needle litter 2 to 3 inches deep, while frequently burned areas had grass and weed ground cover. Differences in nitrogen and organic matter are ascribed to ground cover, while changes in acidity and calcium are attributed to ash following fire.

——— and Barnette, R. M.

1936. Field characteristics and partial chemical analyses of the humus layer of longleaf pine forest soils. Fla. Agr. Expt. Sta. Bul. 302, 27 pp., illus.

Under frequently burned longleaf pine stands, the A_1 horizon, from 2 to 4 inches thick, is more typical of grassland than of forest. The chief source of organic matter is herbaceous roots, mainly grass. With fire protection, an F-layer ½ to ¼ inch thick develops. No continuous H-layer occurs. A period of 8 to 12 years is needed to get a balance between accumulation and decomposition of pine litter. Annual needle fall is from 2,400 to 3,500 pounds per acre. The litter developed under fire protection gives healthy soil condition, with rapid decomposition preventing formation of raw humus and soil degradation. The forest floor conserves moisture and prevents soil surface compaction.

——— and Tissot, A. N.

1936. Some changes in the soil fauna associated with forest fires in the longleaf pine region. Ecol. 17: 659-666, illus.

The A_0 horizon of long-unburned longleaf pine forests supported about 5 times as many microfaunal forms as the herbaceous ground cover of frequently burned areas. The top 2 inches of mineral soils of unburned areas contained 11 times more soil microfauna than corresponding soil from burned areas. It is believed the microfauna are responsible for the fact that soils are more penetrable and better aerated on unburned areas than on burned areas.

Hine, W. R. B.

1925. Hogs, fire and disease versus longleaf pine. South. Lumberman 119 (1544) : 45-46, illus.

The Roberts plots at Urania, La., have demonstrated that fencing is necessary to prevent hogs from destroying all longleaf seedlings. Annual fires will eliminate loblolly and shortleaf reproduction but have no serious effect on the number of longleaf seedlings if the first fire comes when seedlings are at least one year old. Brown spot has skilled a few seedlings on the unburned plot. Longleaf on the unburned plot are about 3 times as tall as on the plot burned 10 times, and have 10 times the basal area at breast height. See Bruce, D., 1947; and Wyman, L., 1922.

Hursh, C. R., and Pereira, H. C.

1953. Field moisture balance in the Shimba Hills, Kenya. East African Agr. Jour. 18 (4) : 1-7.

For the equatorial coastal conditions studied, a high tropical forest was considered to be more favorable to ground-water storage than the adjacent, annually burned grass vegetation.

Jeffers, D. S., and Korstian, C. F.

1925. On the trail of the vanishing spruce. Sci. Monthly 20: 358-368.

Destructive logging followed by fire threatens to eliminate red spruce in the southern Appalachians. On cutover lands where fire has not burned, advance growth present before cutting is developing satisfactorily. But no new seedlings dating from the cutting have appeared. Generally, there is enough advance growth to hold the land for spruce, but not to provide well stocked stands at maturity. Where fire has occurred, the loss of spruce is complete, and in its place are stands of noncommercial fire cherry and yellow birch.

Jemison, G. M.

1943. Effect of single fires on the diameter growth of shortleaf pine in the southern Appalachians. Jour. Forestry 41: 574-576.

A clear distinction is made between the growth of stands and the growth of individual surviving trees after fire injury. Wounding and mortality following a severe fire may cause a material reduction in stand yields, but individual surviving shortleaf pine trees continue to increase in diameter at a normal rate even though their crowns are entirely scorched by a single fire.

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1944. The effect of basal wounding by forest fires on the diameter growth of some southern Appalachian hardwoods. Duke Univ. School Forestry Bul. 9, 63 pp., illus.

A comprehensive study showing that: (1) basal fire wounding has no significant effect on rate of diameter growth or food and water translocation in yellow-poplar and white oak, (2) anatomical changes in phloem and xylem near fire wounds to quickly circumvent the temporary obstruction are universal, (3) slower growth of some wounded scarlet oak trees results from crown injury rather than from physiological or anatomical changes. This slower growth of wounded scarlet oak represents a loss of $0.23 per acre over a single rotation in an average stand of second-growth mixed oak in the southern Appalachians.

Kaufert, F. H.

1933. Fire and decay injury in the southern bottomland hardwoods. Jour. Forestry 31: 64-67.

Fires damage bottomland hardwoods by killing young trees, giving rise to poor-quality sprout stands, and by scarring survivors. It is estimated that fire has caused 90 to 95 percent of decay in merchantable stands.

Keetch, J. J.

1944. Sprout development on once-burned and repeatedly-burned areas in the southern Appalachians. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 59, 3 pp. [Processed.]

On a once-burned area 8 years after burning, dominant sprouts, averaging 10.4 feet in height, are evident, two-thirds of the ground area is covered, and a fine stand is anticipated. By repeated burning, sprouting capacity and growth rate or vigor are not significantly reduced, but only one-third of the ground area is covered and there is evidence of soil deterioration. Sprouting varies by parent tree size and, to some extent, by species.

Korstian, C. F.

1924. Natural regeneration of southern white cedar. Ecol. 5: 188-191, illus.

Discusses the killing effects of fire during dry seasons, the beneficial results during wetter seasons in regenerating the species, and ecological trends following disastrous fires.

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1927. Timber from southern white cedar pays on coastal swamp land. U. S. Dept. Agr. Yearbook 1927, pp. 617-619, illus.

Strip cutting is preferred to seed trees, with controlled slash fires to provide a seedbed of exposed surface peat.

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1937. Perpetuation of spruce on cut-over and burned lands in the higher southern Appalachian mountians. Ecol. Monog. 7: 125-167, illus.

Depletion of southern Appalachian spruce forests is due to fire following destructive logging. Although the most valuable species in the spruce forest, red spruce does not reproduce effectively under conditions of high altitude and the dry surface layer of moss, peat, and soil, which follows cutting and fire. Furthermore, it does not compete vigorously with the associated hardwoods. Thus, cutting practices in this type must be directed toward partial or selective cutting, or even no cutting on those areas reserved for watershed protection.

——— and Brush, W. D.
1931. Southern white cedar. U. S. Dept. Agr. Tech. Bul. 251, 76 pp., illus.

Because of thin bark and highly flammable leaves and twigs, southern white cedar is at all ages very susceptible to fire. However, dense stands of reproduction have sprung up on clear-cut areas following single slash fires that occurred when swamps were filled with water and before dormant seeds in the peat had germinated.

Lee, R. E., and Smith, R. H.
1955. The black turpentine beetle, its habits and control. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 138, 14 pp., illus. [Processed.]

The black turpentine beetle kills trees in stands that have been disturbed by logging, turpentining, fire, hail, wind, lightning, or other insects. Control by burning stumps is not practical; salvage of dead and dying trees and spraying stumps and seed trees with BHC are recommended.

Lemon, P. C.
1946. Prescribed burning in relation to grazing in the longleaf-slash pine type. Jour. Forestry 44: 115-117.

Prescribed burning improves the forage for grazing. Burning can be successfully done if the area selected for burning has an adequate stand of trees, is subdivided into small units, if conditions for burning are favorable, and if the job is done by personnel trained in the use of fire.

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1949. Successional responses of herbs in the longleaf-slash pine forest after fire. Ecol. 30: 135-145.

Herbs are classified into three groups, principal, secondary, and "fire followers." Principal herbs are adapted to persist after burning; the less important secondary herbs react to fire roughly in the same way as do the primary; the fire followers quickly invade a burned area but are largely eliminated by 8 or 10 years of protection.

Lentz, G. H.
1931. Forest fires in the Mississippi bottomlands. Jour. Forestry 29: 831-832.

In the spring of 1931 the bottomlands were dry and damaging fires were burning. Decay losses from 1924-25 fires were becoming more evident, and constituted a clear warning that fire protection is necessary if timber is to be grown on the bottomlands.

Lindenmuth, A. W., Jr., and Byram, G. M.
1948. Headfires are cooler near the ground than backfires. Fire Control Notes 9 (4): 8-9, illus.

In prescribed burning where it is desired to minimize damage to reproduction under 18 inches or so in height, headfires may prove more economical and effective than backfires.

——— Keetch, J. J., and Nelson, R. M.
1951. Forest fire damage appraisal procedures and tables for the Northeast. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 11, 28 pp., illus. [Processed.]

Presents tables for determining average dollar damage per acre according to forest type, stand origin, size class, stand density, season of year, and fire intensity.

Lotti, T.
1955. Summer fires kill understory hardwoods. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 71, 2 pp. [Processed.]

Annual summer fires were more effective than biennial fires.

——— and McCulley, R. D.
1951. Loblolly pine: maintaining this species as a subclimax in the south-eastern United States. Unasylva 5: 107-113, illus.

Summer fires may be needed to kill hardwoods that are too large to be killed by winter fires. At time of regeneration, the pine seedbed can be prepared and the hardwoods checked simultaneously by a pre-seedfall burn. Most favorable season for treatment is September and October.

McCarthy, E. F.
1922. Fire increases dry site type. U. S. Forest Serv., Serv. Bul. 6 (22) : 4-5.

Two fires in the southern Appalachians caused severest damage on dry slopes. Fires favored pines, increased the number of pine seedlings, crippled the mature hardwoods, started disease in the fire scars, and created dense clumps of hardwood sprouts.

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1928. Analysis of fire damage in southern Appalachian forests. Jour. Forestry 26: 57-68, illus.

Analysis of fire mortality and injury of trees by size. Deductions on the elements of damage and problems awaiting solution are made from the data.

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1933. Yellow poplar characteristics, growth, and management. U. S. Dept. Agr. Tech. Bul. 356, 58 pp., illus.

Instances are cited where dense stands of yellow-poplar seedlings follow light fires that remove the leaf litter. Seedlings and saplings are very susceptible to killing by fire, but when the bark becomes a half inch thick or more, yellow-poplar is one of the most fire resistant of eastern trees. Some information on amount of cull following fire wounding.

——— and Sims, I. H.
1935. The relation between tree size and mortality caused by fire in southern Appalachian hardwoods. Jour. Forestry 33: 155-157, illus.

Presents curves showing the relation between tree size and mortality caused by fires. Suggests a method for rating fire intensity by dividing actual mortality in the 3-inch class into 10 intensity classes and associating mortality in other diameter classes to these as reference points.

McCulley, R. D.
1950. Management of natural slash pine stands in the flatwoods of south Georgia and north Florida. U. S. Dept. Agr. Cir. 845, 57 pp.

Prescribed burning can best be done with a 3- to 10-mile northerly wind from December 15 to February 15. Costs can be reduced by spreading the backfire rapidly so that at least 10 acres will be burned per man-hour. Damage may be reduced by burning only the area absolutely necessary, by avoiding cycle—or quota—burning, and by allowing 10 years of complete protection for development of reproduction. Presents curves of relation of height and diameter growth by crown injury classes.

MacKinney, A. L.
1931. Thirteen annual fires in the longleaf pine type. U. S. Forest Serv., Serv. Bul. 15 (37) : 2-4.

During a 10-year period on an annually burned plot, diameter growth was reduced 9 percent and annual volume growth 22 percent.

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1931. Longleaf pines subjected to thirteen years' light burning show retarded growth. U. S. Forest Serv. Forest Worker 7: 10-11.

Average d. b. h. of all trees on the annually burned plot was 4.4 inches and on the unburned plot 5.1 inches. Figures are given for difference in increment and in volume of peeled wood.

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1933. Mortality in longleaf pine pole stand after a hard fire. U. S. Forest Serv., Serv. Bul. 17 (22) : 3.

Table, based on examinations 2 months and 11 months after the fire, shows percentage of trees that died in each of 5 defoliation classes.

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1934. Some effects of three annual fires on growth of longleaf pine. Jour. Forestry 32: 879-881, illus.

On experimental plots burned annually for 3 years mean basal area growth (inside bark) was reduced 42.0± 8.9 percent by burning. Larger trees showed a greater reduction in basal area growth than smaller ones. Reduction in height growth appeared to be negatively correlated with size of tree but was not significant.

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1934. Some factors affecting the bark thickness of second-growth longleaf pine. Jour. Forestry 32: 470-474, illus.

Analysis of 613 trees from burned areas showed that fire measurably reduced bark thickness.

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1935. Effects of a light fire on loblolly pine reproduction. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 9, 2 pp. [Processed.]

Table shows cumulative mortality 7, 26, and 50 weeks after a light fire. Mortality of reproduction was very high.

Mann, J. M.

1947. Prescribed burn versus wildfire. Forest Farmer 7 (2) : 4, illus.

How a prescribed burn in a slash pine area reduced a 15-year accumulation of fuel and how a wildfire on a part of the area not prescribe-burned caused severe damage.

Mann, W. F., Jr.

1954. Direct seeding research with longleaf, loblolly, and slash pines. La. State Univ., School of Forestry, Third Ann. Forestry Symposium Proc., pp. 9-18.

Longleaf should be direct-seeded in November after about 2 inches of rain. A one-year rough is the preferred seedbed on most sites. There should be no fresh burns on or near the area because they attract birds. On dry sandy sites, disking may prevent heavy losses if there is a drought in the first summer. Loblolly seeding on sites dominated by poor hardwoods is best done in November on fresh burns. Falling leaves hide the seed from birds. On open land, spring sowing of loblolly is necessary to prevent freezing damage. Disking appears necessary to reduce grass which overtops loblolly seedlings developing on fresh burns and grass roughs. Slash pine may be sowed in fall with no special site preparation.

——— and Derr, H. J.

1954. Direct seeding of southern pines. South. Lumberman 189 (2369): 115-117, illus.

One-year roughs are usually the best seedbeds for longleaf, although on very dry sites disked strips in one-year roughs may help seedling survival in a dry summer. Fresh burns on or near the seedbed area are highly attractive to migratory birds. Disked strips in one-year roughs probably are the best seedbeds for slash and loblolly.

——— and Rhame, T.

1955. Prescribe-burning planted slash pine. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 96. [Processed.]

See item immediately below.

——— and Whitaker, L. B.

1955. Effects of prescribe-burning 4-year-old planted slash pine. Fire Control Notes 16 (3) : 3-5.

In central Louisiana, a 600-acre 4-year-old slash plantation with moderate but spotty grazing was prescribe-burned in the winter 1952-53 for hazard reduction without serious damage. All burning was against the wind. Fires killed 8 percent of the trees, mostly those under 3 feet tall. Survivors lost 0.25-foot growth the following year. Generally, slash plantations averaging less than 8 feet tall should not be burned, unless weather and fuel conditions are exactly right and experienced men are on hand to do the burning.

Meginnis, H. G.

1935. Effect of cover on surface run-off and erosion in the loessial uplands of Mississippi. U. S. Dept. Agr. Cir. 347, 16 pp., illus.

Run-off and erosion were measured for 2 years in catchment tanks installed under 8 different cover types, including a mature oak forest unburned for 7 years and a scrub oak woodland subjected to severe cutting, frequent fires, and other abuses. The scrub oak permitted 15 times as much soil loss and 10 times as much direct run-off as the old-growth oak forest, but only 0.3 to 1 percent of the soil loss and 15 percent of the run-off allowed by a barren abandoned field or cultivated land.

Minckler, L. S.

1944. Third-year results of experiments in reforestation of cutover and burned spruce lands in the southern Appalachians. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 60, 10 pp., illus. [Processed.]

A combination of burning and grazing followed by planting may be the cheapest and most effective treatment for establishing spruce.

Muntz, H. H.

1947. Prescribed burning of longleaf plantations. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 49. [Processed.] *Also in* Naval Stores Rev. 57 (11) : 5.

See Wakeley, P. C., and Muntz, H. H., 1947.

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1948. Slash pine versus loblolly in central Louisiana. Jour. Forestry 46: 766-767, illus.

Part of a mixed-species planting was burned after 6 years. At 10 years, loss in survival, apparently due to burning, was 20 percent for slash against 34 percent for loblolly; and loss in height was 1 foot for slash and 5 feet for loblolly, indicating that slash pine is more fire resistant under these conditions.

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1954. How to grow longleaf pine. U. S. Dept. Agr. Farmers' Bul. 2061, 25 pp., illus.

Longleaf is more fire resistant than other southern pines, and may be the only species that will grow successfully where fire protection is inadequate. In longleaf management, fire is used to prepare sites for seeding or planting, control brown spot, reduce wildfire hazard, and control competing hardwoods. Indiscriminate burning has no place in longleaf management. Since repeated burning may cause erosion and watershed damage, hilly land may best be managed for other species. Periodic prescribed burning destroys needles and dead rough, speeding growth of new grass and making it more available to cattle.

Nelson, R. M.

1935. A method for rating forest fire intensity. U. S. Forest Serv. Appalachian Forest Expt. Sta. Tech. Note 8, 1 p., illus. [Processed.]

Five classes of fire intensity are arbitrarily established, based on percentage of 3-inch trees killed.

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1951. More facts are needed on prescribed burning. Forest Farmer 10 (8) : 5.

A popular account of the importance of temperature in the use of prescribed fire, i.e., possibility of obtaining satisfactory results in reducing fuels on cold winter days, hardwood control on hot summer days, and brown-spot control by the use of headfires, which are cooler near the ground than backfires.

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1952. Observations on heat tolerance of southern pine needles. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 14, 6 pp., illus. [Processed.]

Needles of longleaf, slash, loblolly, and pitch pine, when immersed in a water bath, had about the same lethal temperatures.

——— and Sims, I. H.

1934. Fire wounds have close relation to exterior discoloration of bark. U. S. Dept. Agr. Yearbook 1934, pp. 218-220, illus.

See item immediately below.

——— Sims, I. H., and Abell, M. S.

1933. Basal fire wounds on some southern Appalachian hardwoods. Jour. Forestry 31: 829-837, illus.

A study of oaks and yellow-poplar wounded by a spring fire in Virginia. There was a fairly high correlation between the area of discoloration and the area of wound for all but scarlet oak, which is highly susceptible to wounding. Of the species studied, yellow-poplar was the most resistant, scarlet oak the least resistant, and black, white, and chestnut oak intermediate.

Osborne, J. G.

1937. Pulpwood and forest fires. Paper industry 19: 661-664.

Although most fires may appear to do little damage to southern pine stands, they take an immense toll of seedlings needed for full pulpwood production. Fires in logging slash are particularly damaging; logged areas should get extra protection. Loblolly-shortleaf stands need better protection than longleaf.

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1938. Effects of burned faces on later turpentining. Forestry News Digest, Southern ed., May issue, p. 23.

Two years after a severe April 1934 fire in southeast Georgia, turpentining was resumed on trees with burned faces. The operator used the minimum jump streak that exposed "sufficient" producing wood. Jump streaks on the windward side were ⅔ inch lower than on other sides, and were ½ inch higher for each additional 4 feet of stem scorched (and averaged 2¼ inches). Slash pine showed 6 percent more dry-face than longleaf, leeward faces 12 percent more than windward, and small trees more than large trees.

——— and Harper, V. L.
1937. The effect of seedbed preparation on first-year establishment of longleaf and slash pine. Jour. Forestry 35: 63-68, illus.

Longleaf and slash pine seed were sowed on small screened plots in northern Florida in the winters 1933-34 and 1934-35. One year after seeding, survival counts indicated about twice as many longleaf established on plots burned one year before seeding or disked just before seeding, and 3 to 4 times as many on plots spaded or burned just before seeding, as on plots on 3- or 4-year roughs. Slash plots indicated a similar but less consistent effect of rough. The 1933-34 disked plots had notably high survival, possibly because of moisture retention in the dry 1934 summer. Site preparation does not seem so important for slash, which has frequent and abundant seed crops, as for longleaf, with its infrequent seed years. Burning immediately or one year before longleaf seed fall will improve germination or survival, and either method should give satisfactory reproduction if it successfully combats the bird and rodent problem.

Pessin, L. J.
1939. Effect of the treatment of ground cover on the growth of longleaf pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 25. [Processed.]

Longleaf pine grown in containers for 2 years with grasses were ½ as large as those with no grass. Burning grass (annually, with seedlings protected against defoliation) resulted in seedlings nearly as large as where there was no grass. See Pessin, 1944, for final report.

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1942. Stimulating the early growth of longleaf pine seedlings. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 44. [Processed.]

See item immediately below.

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1944. Stimulating the early height growth of longleaf pine seedlings. Jour. Forestry 42: 95-98.

Removing grass competition by repeated hoeing greatly stimulated longleaf seedling growth, in comparison to no treatment, or to site preparation by spading, or winter burns for 3 successive years (during burns the seedlings were covered with large crocks). Four years after seeding, hoed seedlings averaged 26 inches in height and all others 5 inches. (According to the 1946 Annual Report of the Southern Forest Experiment Station, after 8 years these heights were 15 feet and 7.5 feet with no significant differences between spading, burning, and check.)

——— and Chapman, R. A.
1944. The effect of living grass on the growth of longleaf pine seedlings in pots. Ecol. 25: 85-90.

Longleaf seedlings were grown for 2 years in 1-gallon cans with and without grass, and with 250 or 500 ml. of water added per week. Average dry weight was significantly greater with no grass. Without grass, neither mulching nor amount of water affected growth significantly. Average growth of seedlings where *Andropogon scoparius* was burned each winter (with seedling foliage protected) was greater than where grass was clipped twice a year, which in turn was greater than where grass was untouched. Similar differences did not appear for mixtures of other grasses and forbs for these 3 treatments. Amount of water had a very significant effect on growth of seedlings in competition with *A. scoparius*, but not with other grasses. (Weight of grasses produced was not reported.)

Pomeroy, K. B.
1948. Observations on four prescribed fires in the Coastal Plain of Virginia and North Carolina. Fire Control Notes 9 (2 and 3) : 13-17.

The effect of fires of different severity on killing of small hardwoods and on fuel consumption.

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1950. Twenty years without fire protection. Forest Farmer 10 (3) : 12, illus.

A spring wildfire in a cutover loblolly pine stand destroyed all pine reproduction and all hardwoods up to 2 inches in diameter but was followed by a bountiful seed crop and well-stocked stands of reproduction. Ten years later a second wildfire again destroyed all reproduction, and two years were required to produce a seed crop. The delay enabled a vigorous stand of hardwood sprouts to become established; these sprouts are likely to assume dominance unless treated.

——— and Barron, N. T.
1950. Hardwoods vs. loblolly pines. Jour. Forestry 48: 112-113.

The use of fire, scarification of seed bed, and silvicides in the management of loblolly pine.

Putnam, J. A.
1951. Management of bottomland hardwoods. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 116, 60 pp. [Processed.]

During severe fire seasons, once every 5 or 8 years, fires spread rapidly, killing all tree reproduction under 10 years old, and wounding the survivors. On bottomland hardwood areas, fire once every 10 years precludes the practice of forestry.

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1953. Management possibilities in upland hardwoods, if any. La. State Univ., School of Forestry, Second Annual Symposium Proc., pp. 63-69.

Controlled fire cannot be used in pine-hardwood areas if the hardwoods are to be carried 30 to 40 years. Prevalence of fire on upland pine sites contributes to the poor grade of hardwoods found there. Fire exclusion will increase production of good hardwoods.

Roth, E. R., and Sleeth, B.
1939. Butt rot in unburned sprout oak stands. U. S. Dept. Agr. Tech. Bul. 684, 43 pp., illus.

Sprout stands that develop after severe burns have less decay than those resulting from cutting operations without fire. Fire preceding the establishment of a stand kills the cambium and latent buds above the ground line on the stumps. Sprout regeneration is thus forced to come from buds at or below ground level and such sprouts often escape infection from the parent stump.

Shepherd, W. O.
1952. Highlights of forest grazing research in the Southeast. Jour. Forestry 50: 280-283, illus.

Winter burning greatly increased the protein and mineral content of native grasses until they reached full leaf stage. Thereafter forage quality on burned and unburned range was fairly similar. Cattle gains were three times higher during the spring. Burning alone had little influence on density of native forage species but burning combined with heavy grazing reduced the density of bunchgrasses and favored the invasion of low-growing species, such as carpetgrass.

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1953. Effects of burning and grazing flatwoods forest ranges. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 30, 2 pp. [Processed.] *Also in* Naval Stores Rev. 63 (12) : 17, 20.

Summary of 7-year study of burning longleaf-slash pine forest range at intervals of 1, 2, and 3 years; ecological trends with and without grazing, chemical composition of forage, diet and weight gains of young cattle, fuel accumulation, tree reproduction. General effect of tree cover on understory vegetation. Based on Halls, Southwell, and Knox, 1952.

——— Dillard, E. U., and Lucas, H. L.
1951. Grazing and fire influences in pond pine forests. N. C. Agr. Expt. Sta. Tech. Bul. 97, 57 pp., illus.

With protection from grazing, burning favored cane in competition with shrubs, but burning increased cane's susceptibility to grazing damage. Fires may be essential for regenerating pond pine stands.

——— Southwell, B. L., and Stevenson, J. W.
1953. Grazing longleaf-slash pine forests. U. S. Dept. Agr. Cir. 928, 31 pp., illus.

From March to September cows spent a high proportion of their time on areas prescribe-burned the previous winter, even though these areas were closely grazed and forage limited. Cattle gains were influenced by amount of burned area available. After September, cattle were more willing to graze unburned areas where forage was more abundant. Grazing capacity during the spring and summer should be based entirely on the burned acreage; at least 6 acres per cow appears to be needed.

Siggers, P. V.
1934. Observations on the influence of fire on the brown-spot needle blight of longleaf pine seedlings. Jour. Forestry 32: 556-562, illus.

A single fire will greatly reduce brown-spot infection in longleaf seedling stands for the first season and often to a lesser extent for the second season. This permits retention of foliage through the second season—a necessity for seedling growth. Before longleaf seedlings emerge from the grass, controlled winter burning at 3-year intervals can be used for disease control.

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1935. Slash-disposal methods in logging shortleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 42, 5 pp., illus. [Processed.]

Piling and burning reduces fire hazard immediately, but costs twice as much as lopping and scattering, and creates unfavorable soil conditions under piles. Neither lopping and scattering nor piling have enough advantage over pulling tops to defray the cost. There is little fire hazard after 3½ years, whether slash is treated or left.

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1944. The brown spot needle blight of pine seedlings. U. S. Dept. Agr. Tech. Bul. 870, 36 pp.

Single fires greatly reduced the disease for the first season and often to a lesser extent for the second. Occasionally, reduction of the disease was still evident after three seasons. A 45-acre fire in a 6-year rough reduced the disease for 1 year but only slightly at the end of 2 years. There was a flight of air-borne spores from dense stands of infected seedlings surrounding the burn 8 weeks after the fire, which may explain the brief sanitary effect. Cattle attracted to the burn by green grass may have helped transfer conidia from infected to healthy needles. Although many fires stimulate growth by reducing the disease for 2 years, even a thousand-acre burn may not be effective if the burn is surrounded by extensive sources of inoculum (such as dense infected seedling stands).

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1945. Controlling the brown spot needle blight of longleaf pine by prescribed burning. AT-FA Jour. 8 (1) : 11. *Also in* Naval Stores Rev. 55 (25) : 4, 8 *and* Forest Farmer 5 (1) : 8.

Brown spot seriously affects longleaf seedling growth when the needle kill on a sample of 100 or more seedlings averages 35 percent. Longleaf seedlings should not be burned until they are in their second season of growth. A good time to burn is in late winter prior to spring growth and again in the third winter thereafter, provided most of the seedlings have become badly reinfected. The duration of disease control by a single fire is affected by the size of area burned, and the presence or absence of nearby dense stands of infected seedlings.

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1949. Fire and the southern fusiform rust. Forest Farmer 8 (5) : 16, 21, illus.

Fires in six young slash pine plantations in Louisiana and Mississippi killed branches with fusiform cankers, and thus reduced the number of cankered trees. But there were more new infections on the burned plots than on unburned check plots, possibly because fire induced an earlier break in winter dormancy and provided more tender foliage and shoots when spores were flying. Thus, prescribed burning cannot be recommended to reduce amount of fusiform rust.

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1955. Control of the fusiform rust of southern pines. Jour. Forestry 53: 442-446.

This general discussion of fusiform rust includes the consideration of fire included in the reference immediately above. A single winter fire may kill some cankered branches but if it kills needles but not branches, there will be an unusually early spring increase in new needles and shoots when conditions favor pine infection. The end result of single fires was an increase in number of new cankers.

Sims, I. H.
1932. Establishment and survival of yellow-poplar following a clear cutting in the southern Appalachians. Jour. Forestry 30: 409-414, illus.

Although the first four years following cutting showed an advantage in number of established seedlings of burning over not burning, subsequent competition from ferns and other vegetation nearly eliminated the initial seedling stand.

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1932. Specific differences in basal wounding by fire of southern Appalachian hardwood trees. Abstract in Jour. Elisha Mitchell Sci. Soc. Oct.

An abstract based on a study of 300 mixed hardwood trees following a spring forest fire. The study indicates the relation between external bark discoloration and wound size.

Smith, L. F., Campbell, R. S., and Blount, C. F.
1955. Forage production and utilization in longleaf pine forests of south Mississippi. Jour. Range Mangt. 8: 58-60, illus.

Protein and phosphorous contents of ungrazed grass were only slightly higher on burned than unburned areas. Although these differences were unimportant, cattle preferred to graze on fresh burns, where they utilized from 60 to 90 percent of the forage, as against averages of 13 and 19 percent on unburned range.

Stephenson, G. K.
1955. Better seedling survival is goal of new research. Texas Forest News 34 (3) : 3, 7, illus.

Reports on an excellent stand of first-year seedlings established on a prescribed burn. The stand survived the 1952 drought. The removal of competing trees by cutting, hardwood control, or fire may make more moisture available for seedlings.

——— and Young, D.
1954. 1955 pine cone crop should influence forest management. Texas Forest News 33 (3) :4, 6-7.

Suggests that on selected areas, where competing hardwoods are small and vulnerable, owner may use prescribed fires to prepare stands for reproduction.

Stone, E. L., Jr.
1942. Effect of fire on radial growth of longleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 43. [Processed.]

1,200 longleaf pine increment cores from Mississippi and Louisiana were examined. Trees less than 6 inches d. b. h. lost 0 to 65 percent radial growth in the first year after a fire. The average loss was 23 percent. Larger trees lost up to 35 percent, averaging 19 percent. Usually the second year's growth was essentially normal.

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1944. Effect of fire on taper of longleaf pine. Jour. Forestry 42: 607.

Fires causing 50 percent or more defoliation of longleaf pine 5 to 6 inches d. b. h. reduced diameter growth most at breast height and successively less at heights up to 20 and 28 feet. This reduction decreased stem taper.

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1953. Forest soil problem analysis on the Crossett area. U. S. Forest Serv. South. Forest Expt. Sta., 25 pp. [Processed.]

Discusses concern over site deterioration through continuous cropping of pines, removal of hardwood by fire or timber stand improvement measures, or by direct fire effects. There is no evidence of much effect on site by the first two, but where fire is frequent enough to keep the soil bare much of the time, physical deterioration may be rapid. Existing studies indicate only minor effects by single fires on water entrance into soil and on relative supply of nutrients in Coastal Plains soils.

Suman, R. F., and Carter, R. L.
1954. Burning and grazing have little effect on chemical properties of Coastal Plain forest soils. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 56, 2 pp. [Processed.]

After 8 years of grazing and several rotations of winter burning, soil organic matter, phosphate, and potash were practically the same as for ungrazed unburned areas.

——— and Halls, L. K.
1955. Burning and grazing affect physical properties of Coastal Plain forest soils. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 75, 2 pp., illus. [Processed.]

Volume-weight and water-absorbing properties of Coastal Plain soils are altered through compaction effects of grazing when litter is removed by burning.

Toole, E. R., and McKnight, J. S.

1955. Fire and the hapless hardwood. South. Lumberman 191 (2393) : 181-182, illus.

A 1,200-acre fire in November 1952 burned through a 70-acre experiment in the management of bottomland hardwoods. Losses included complete kill of trees up to 1 inch d. b. h., mortality of two-thirds of 1- to 2-inch trees, and 35 percent kill of 3-inch to 5-inch trees. With headfire or where there was logging slash, 90 percent of the trees over 6 inches were killed or severely damaged. Even where flames were least hot, losses of larger trees were 20 percent. Guides for salvage and for estimating extent of rot are included.

——— and McKnight, J. S.

1955. Fire damage to hardwood trees shown in Delta. Miss. Farm Res. 18 (9) : 1, 8, illus. *and* Miss. Agr. Expt. Sta., Serv. Sheet 432, 2 pp., illus.

Substantially the same as article cited immediately above.

Verrall, A. F.

1936. The dissemination of Septoria acicola and the effect of grass fires on it in pine needles. Phytopathology 26: 1021-1024.

Temperatures that kill needle tissue kill the brown spot in that tissue. Needles with scorched tips may have brown-spot infections in green basal portions after fire.

Wahlenberg, W. G.

1934. Dense stands of reproduction and stunted individual seedlings of longleaf pine. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 39, 16 pp., illus. [Processed.]

Longleaf seedlings may remain stunted for long periods in overdense stands, and be repeatedly injured by brown spot or fire. Brown spot tends to damage the larger seedlings, thus retarding expression of dominance, while fire often does more damage to smaller seedlings, thus promoting expression of dominance.

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1935. Effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. Jour. Forestry 33: 331-338.

With fire protection, loblolly and slash pines become established on former longleaf lands. Ten years of protection affected physical soil properties favorably, but chemical properties unfavorably. Effect of 4 annual winter burns on longleaf cone production was negligible. Fire just before seedfall increased the number of seedlings that germinated and started growth. Fire 3 months after seedfall killed most longleaf seedlings. Neither complete fire exclusion nor annual burning results in satisfactory longleaf regeneration. Probably periodic controlled burning will improve longleaf seedling growth. See Wahlenberg, W. G., Greene, S. W., and Reed, H. R., 1939.

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1935. Fire in longleaf pine forests. U. S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 40, 4 pp. [Processed.]

Controlled burning may be used for longleaf seedbed preparation and disease control, and for hazard reduction in all southern pines, saplings and larger. Controlled burning requires planning and trained personnel, and benefits must be weighed against costs and damage.

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1936. Effect of annual burning on thickness of bark in second growth longleaf pine stands at McNeill, Miss. Jour. Forestry 34: 79-81.

Two adjacent stands had been burned frequently prior to 1924. One was burned annually from 1924-34 and the other protected against fire. Measurements on 1,400 trees, from 2 to 8 inches in diameter, indicated that the double bark thickness of unburned trees was 0.066 inch greater than that of annually burned trees. Neglecting this bark difference might cause errors of 2½ percent in computed volume, but for most purposes the difference is negligible.

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1946. Longleaf pine. Pack Forestry Foundation, Washington, D. C., in cooperation with Forest Serv., U. S. Dept. Agr. 429 pp., illus.

This comprehensive monograph reviews all literature through 1944, and includes some otherwise unpublished information.

——— Greene, S. W., and Reed, H. R.

1939. Effects of fire and cattle grazing on longleaf pine lands as studied at McNeill, Mississippi. U. S. Dept. Agr. Tech. Bul. 683, 52 pp., illus.

Annual winter burning of uncontrolled intensity retarded growth of longleaf pine saplings by ⅕ in diameter and ¼ in height in a 5-year period. Neither annual burning, which defoliated seedlings, nor fire exclusion, which permitted brown spot to defoliate seedlings, was successful in bringing longleaf seedlings out of the grass. Burned-over soils had slightly more favorable chemical characteristics and slightly less favorable physical characteristics than unburned soils. Successful regeneration of longleaf pine where brown spot is present may depend on a system of periodic controlled burning. Annual winter burning yielded better forage than did fire exclusion, which permitted pine litter and accumulated dead grass to reduce growth of grass and legumes and the number of herbaceous plants. On burned areas, cattle gained 37 percent more in 7 months of summer grazing than on unburned areas. Grazing affected compaction of surface soil about half as much as fire. With unburned and ungrazed areas as a comparison, unburned and grazed soils were 84 percent as penetrable; burned and ungrazed, 67 percent; and burned and grazed, 56 percent.

Wakeley, P. C.

1931. Effect of a single fire on planted slash pine. U. S. Forest Serv. Forest Worker 7 (2) : 11.

A fire in January 1930 burned half of a 4-year-old slash pine plantation about 8 to 9 feet tall. A year later, survival was 8.2 percent lower on the burned half and height was 1.2 feet less. The plantation was in south Mississippi.

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1931. The inside story of slash pine on areas subject to frequent fires. U. S. Forest Serv. Forest Worker 7 (1) : 11-12.

In southeast Louisiana, a good slash pine seed crop in 1924 regenerated 1,000 acres of cutover land. The area had been frequently burned prior to this time but thereafter escaped fire until the winter of 1928-29, when most of it burned. Other fires the following winter finished the job, and today there is no visible evidence that the area was once well stocked with slash pine seedlings.

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1935. Artificial reforestation in the southern pine region. U. S. Dept. Agr. Tech. Bul. 492, 115 pp.

In southern pine plantations, longleaf is most fire resistant, slash next; loblolly and shortleaf are most readily damaged by fire. However, fire defoliation generally causes a growth loss. All pines increase in fire resistance with increasing age. Generally, mortality for slash and loblolly in the first 2 or 3 years is essentially complete. Winter fires are less damaging than fires in the growing season. It is a moot question whether freedom from brown spot obtained by burning completely offsets the damage done by the fires themselves.

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1944. Where and how can the pines be reproduced. South. Lumberman 169 (2129) : 140-145, illus.

A survey in four widely separated counties in Alabama indicated (among several other minimum requirements) that freedom from fires for at least 5 years is needed to get adequate loblolly or shortleaf reproduction. See Brinkman, K. A., and Swarthout, P. A., 1942.

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1947. The 1947 cone crop and forest fires. U. S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 51. [Processed.] *Also in* Forest Farmer 6 (12): 5 *and* South. Lumberman 175 (2201) : 184.

To take advantage of the good 1947 pine seed crop, forest fires must be excluded until longleaf seedlings are at least 1 year old and other pines are 5 feet to 10 feet tall.

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1954. Planting the southern pines. U. S. Dept. Agr., Agr. Monog. 18, 233 pp., illus.

Longleaf is the most fire-resistant southern pine, slash next, and shortleaf and loblolly are the most easily fire damaged, but shortleaf up to 4 years old sprouts readily after fire. Planting site preparation by burning may not improve survival but may reduce planting and fire protection costs, and may retard brown-spot infection of longleaf and reduce rodent concentrations. But burning will kill small volunteer slash and loblolly, and may attract cattle to the area. Burning may also increase exposure to freezing or spring insolation. Prescribed burning of longleaf plantations for brown-spot control should be done in January or February before more than 35 percent of the needles are killed by the disease.

——— and Muntz, H. H.

1947. Effect of prescribed burning on height growth of longleaf pine. Jour. Forestry 45: 503-508, illus. *Also in* Naval Stores Rev. 57 (30) : 11, 24-25, illus.

A 40-acre longleaf pine plantation in central Louisiana established in 1935 was prescribe-burned January 1938, at which time brown-spot infection averaged 37 percent needle kill. It was burned a second time in February 1941. In July 1946, survival was the same as on a nearby unburned 60-acre plantation, but height growth on the burned plantation was far superior. In the burned plantation, 64 percent of the living trees were above 4½ feet in height as compared with 22 percent on the unburned. Much of the superior growth seems due to brown spot control by fire.

Wyman, L.

1922. Results from sample plots in southern pines experiments. Jour. Forestry 20: 780-787.

A report on 5 sets of plots at Urania, Louisiana, including the Roberts plots, on which were observed the effects of annual burning (starting a year after germination) and fencing to exclude hogs. Hogs destroyed all longleaf on unfenced plots in the first year. The fires did not materially affect survival of longleaf but killed all shortleaf and loblolly. In September 1921, the 8-year-old longleaf averaged 22 inches in height on the unburned plot but only 11 inches on the burned. The few trees killed by the January 1921 fire were practically all in the 6-inch to 18-inch height class. None over 2.5 feet in height was killed. The increased fire hazard on the protected plot was demonstrated by a breakover that killed or caused to sprout 39 percent of the trees as against 21 percent on the frequently burned plot (which had less fuel). Brown-spot disease weakens longleaf seedlings and kills some. Only 43 percent of the trees on the burned plot were diseased 9 months after burning, as against 66 percent on the unburned plot. It is suggested this may be due to fire killing of diseased trees. See Bruce, D., 1947; and Hine, W. R. B., 1925.

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