Prescribed Burning and Air Quality—Current Research in the South

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IN the southern United States, we have learned to use fire as an effective, inexpensive tool for applying specific management treatments to our forests. Hazard or rough reduction is the principal use of prescribed fire, but seedbed and site preparation, control of undesirable species, and wildlife habitat improvement are also common uses. Prescription fires play an integral part in reducing the severity of damage resulting from uncontrolled wildfires. It has been demonstrated that acreage loss per wildfire can be dramatically reduced by periodic hazard reduction burns. To do this, in excess of 2 million acres of forest land are treated annually by low-intensity prescription fires in our 13 southern states. In this manner, fuels are managed so that excessive fuel weight buildups are not prevalent on widespread areas.

But, with all the benefits, concern for smoke dissipation has not involved management directly. We are only beginning to realize how serious pressure groups are regarding uncontrolled smoke. And, quite frankly, we are not in a position to say precisely what effect the burning of forest fuels has on air quality. It can be deduced, however, that with widespread uncontrolled fire would come air quality crises. And these crises would quite likely be the result of outlawing the use of prescribed fire in our southern states.

The preliminary studies were to examine the products of combustion of forest fuels and their dispersion. This information is necessary in formulating the principles required for effectively managing smoke plumes. At the present time, we know very little about the meteorological conditions that favor smoke dispersion. However, it may be possible to set up broad guidelines that will minimize air quality problems resulting from prescribed burning: For instance, we know that burning under a neutral or unstable lapse rate will reduce low-level pollution, that burning following a cold frontal passage is conducive to good smoke dispersion, and that burning when the mixing layer is greater than 2,000 feet is desirable from a smoke dispersion standpoint. There is a need, though, for more specialized criteria when burning adjacent to smoke-sensitive areas, such as large cities and along interstate highways. Some of these burning criteria have been established for regional areas in the United States (Beaufait and Cramer, 1969; Oregon Forestry Dept., 1969), but the data are incomplete. Little is known about the source strength of particulates and gases when the fuels are burned under different conditions. Considerable work is necessary to determine the rate of dispersion for smoke particles with given physical and dynamic properties. The possibilities for manipulating the amount of material released into the air are many.

To date our research effort has been exploratory in nature, with equipment and manpower requirements being investigated and research methods being formulated. What follows is a description of the exploratory pilot study results. Our research program is currently divided between controlled environment (laboratory studies) and natural environment (field studies).

CONTROLLED ENVIRONMENT

The type and quantity of particulates and gases produced from burning forest fuels are largely functions of weather, fuel con-

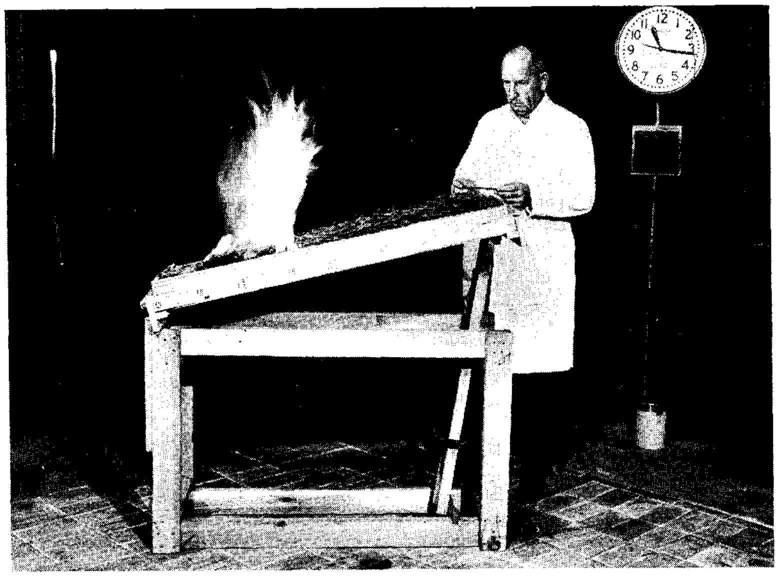

FIG. 1. Environmental conditions are closely controlled inside the combustion room at the Southern Forest Fire Laboratory. Illustrated here is one method used for simulating head fires and backfires.

dition, and firing-technique variables. In the combustion room (Fig. 1) at the Southern Forest Fire Laboratory, we are able to control many of these variables and manipulate them as desired while studying the emission response of the burning fuel. It is hoped that information derived from these controlled studies can be used as a basis for fire prescriptions to minimize the production of unfavorable products of combustion.

In a recent study, litter beds of loblolly pine (*Pinus taeda*) were burned and the particulate output monitored in our combustion room. Results of these limited tests indicate that simulated backfires (fires burning downslope) produce, on the average, 35 percent less particulate than simulated head fires (fires burning upslope).

We are working closely with Dr. Ellis Darley of the Statewide

Air Pollution Research Center, University of California, Riverside. He has evaluated combustion products from orchard trimmings and agricultural wastes and has recently received a grant for studying emission products from the burning of natural forest fuels. At the Southern Forest Fire Laboratory, our system of gas analyzers (CO, CO_2, and total hydrocarbon) and particulate sampling equipment is similar to the equipment used by Dr. Darley (Darley, *et al.* 1966). Future plans call for exchanging samples of southern forest fuels to cross-check results.

Many research findings from the Laboratory will require verification under field conditions. There is always the possibility that small fires burning under closely controlled conditions in the laboratory will fail to represent the field situations. There are other areas of the overall research problem involving dispersion principles that cannot be readily confirmed by small laboratory fires. It is necessary to cope directly with natural environmental conditions in these areas of research.

NATURAL ENVIRONMENT

Pilot studies have been initiated to examine air quality over a regional area during an active prescribed burning period and to complete case studies for specific prescribed fires.

For one study, high-volume air samplers were located, two to a tower, at seven different fire lookouts over an eight-county area in middle Georgia. The sampler draws about 50 cubic feet of air per minute through an 8- by 10-inch piece of glass-fiber and traps nearly 100 percent of the particles from 0.3 to 100 microns in size. The particulate weight per cubic meter of air is determined by substracting the clean filter weight from the used filter weight and dividing this by the total volume of air sampled during the sampling period. The filters were changed between 0800 and 1000 each morning in both the sampler located at the tower base and the sampler located 100 feet above ground level (Fig. 2). The samplers were operated for a 2-week period during February 1970 that included two distinct weather situations, one when

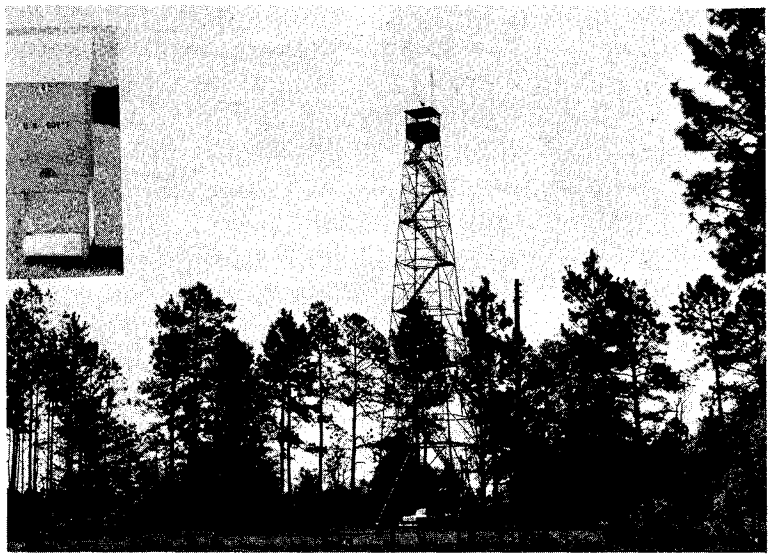

FIG. 2. A typical Georgia Forestry Commission fire lookout tower with one high-volume air sampler located on the second landing below the cab and the other one at the base of the tower.

prescribed burning activity was minimal because of wet weather and another when activity was moderately heavy following a cold front passage. The locations of the smoke plumes observed for these 2 days are shown in Figure 3.

Weights of particulates collected daily measured in $\mu g/m^3$ (microgram per cubic meter) for this period correlated with the number of observed smoke plumes (Fig. 4). Individual data points in Figure 4 are average particulate weights for all samplers in operation during each 24-hour sampling period. Predominant wind directions are indicated for each day. Number of observed smoke plumes is the total located by day by the fire lookouts in the eight-county area. No record of acreage burned by prescribed fires is kept; however, it is quite likely that the frequency of larger-size burns increased as burning conditions improved. Beginning on February 9, following the passage of a cold front, burning conditions improved with each day

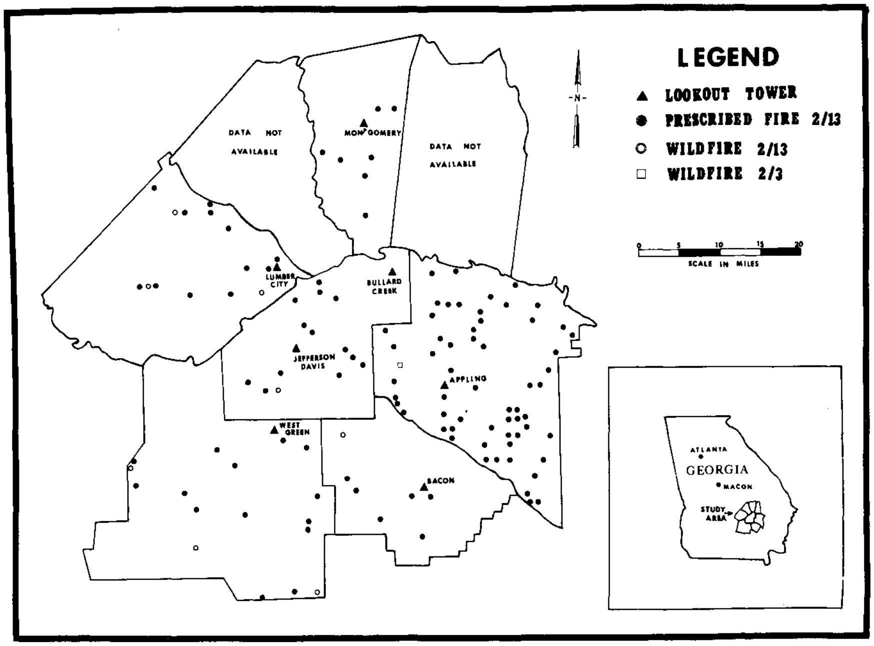

FIG. 3. Location of smoke plumes as reported by fire lookouts for two dates in February. For February 13, 118 smoke plumes were recorded while only one plume was observed February 3, 1970.

for the next 4 days. The cold front was accompanied by a trace of precipitation. During this period, however, there is reason to believe that dust particulates gradually increased as a result of more agricultural activity during the dry weather. Improved methods for isolating dust particles from smoke particles are needed.

We found a significant decrease in particulate concentration with height. The particulate samples were stratified into two groups: samples collected under predominantly westerly winds, and samples collected for other winds. Indications are, for this region and weather conditions with a predominantly west wind, that particulate concentrations are approximately 10 percent less at the 100-foot level than at the surface. Under other winds, particulate concentrations averaged 5 percent less at this height. Further sampling and analysis of these data are needed to verify these results.

Particulate concentration information for rural areas is largely unavailable (U. S. Dept. HEW, 1969). Ranges in particulates are even more difficult to obtain for a regional area. This information is needed since the particulate concentrations developed in rural areas contribute to the background concentration for the urban areas.

The particulate samples collected indicate that there are mechanisms which cleanse the atmosphere. Following Sunday, February 1, when little burning activity was recorded, there were 2 days of rain (0.67 inch on February 2 and 0.78 inch on February 3). Particulate concentrations dropped to 13 $\mu g/m^3$ on the 2nd, but increased to 27 $\mu g/m^3$ on the 3rd. Apparently the effect of low, commercial activity on Sunday, combined with rain, produced relatively clean air conditions.

During the 2-week period the samplers were in operation (Fig. 4),

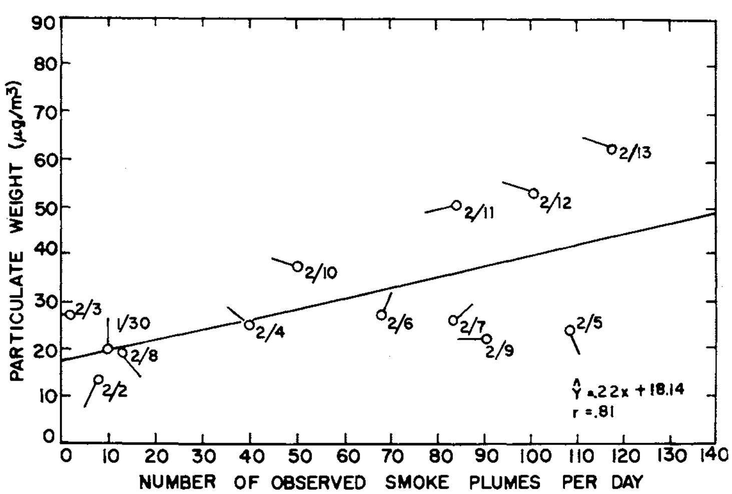

FIG. 4. Average particulate weight per cubic meter of air sampled for each 24-hour period as correlated with the number of observed smoke plumes recorded during each 24-hour period. The data points represent samples collected January 30, and February 2 through February 13, 1970. A line from each data point extends toward the direction from which the wind originated.

only 5 subsamples exceeded 80 $\mu g/m^3$ of particulates. The Department of Health, Education, and Welfare has established as a goal for cities a particulate loading of 80 $\mu g/m^3$. In general, weather conditions prevailing during this period were not of the stagnant airmass type which restrict dissipation of particulates and gases. Analysis of atmospheric soundings indicates that mixing depth were sufficient to enhance smoke dissipation during the data collection period.

In studying the dispersion characteristics of smoke plumes, it is necessary to know the number and size of particles for different spatial points within the plume. Dr. Roy O. McCaldin and Dr. Robert Sholtes of the University of Florida operate an instrumented aircraft for the study of general air quality and specific air pollution characteristics of smoke plumes. Instrumentation includes a Bausch and Lomb 40-1 optical particle counter that counts the number of particles equal in size and larger than a predetermined lower limit of 0.3, 0.5, 1.0, or 2.0 microns.

To study particulate production under field conditions, we instrumented a typical prescribed burning operation near Lumber City, Georgia. Our objective was to establish a network of ground samplers and fly McCaldin and Sholtes' smoke particle counter through the plume to establish techniques for collecting the data needed to make calculations of smoke particle concentration and dispersion. Within the area burned, there was one block of about 12 acres which had been clearcut and another 50 acres adjacent to the clearcut area that had been commercially thinned. Aside from this, the fuels were uniform over the 370-acre, 20-year-old slash pine (*Pinus elliottii*) plantation. The major part of the area had about 3 tons-per-acre available pine litter fuel, with fuel in the thinned area exceeding this amount. The clearcut area had approximately 9 tons of available fuel per acre.

The burning operation began at 1230 on March 13 with a variety of firing techniques: Backfires, flank fires, head fires, and spot fires. The fires burned throughout the afternoon on Friday, all that night, and up to an 1800-hour burnout time on Saturday. Winds persisted between 260° and 300° during this period. Fire intensity and heat-yield variation was quite large. Consequently, the plume structure close to the fire was fragmentary (Fig. 5). The sky was overcast,

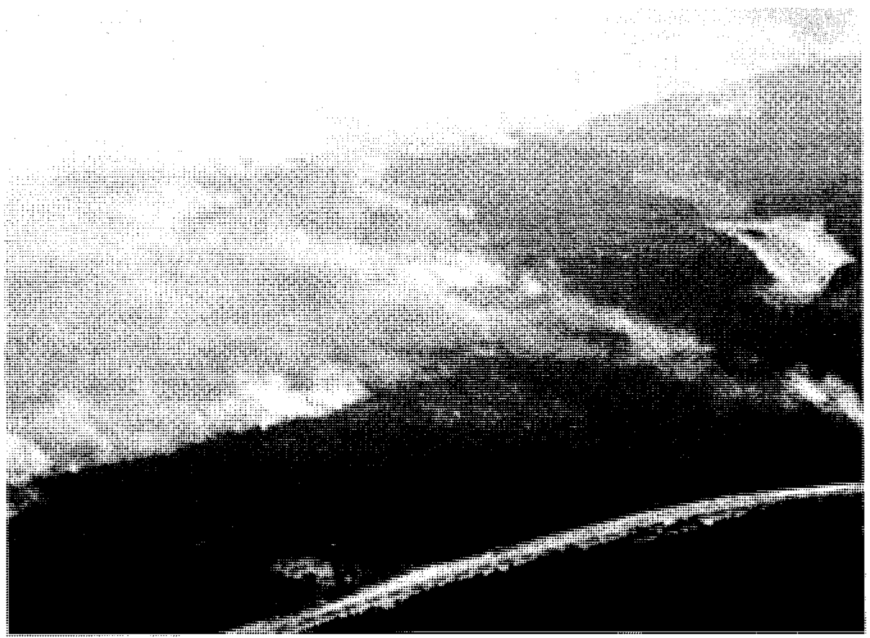

FIG. 5. Smoke plume directly above the slash pine plantation illustrating the variation in smoke concentration resulting from the variable burning techniques employed.

with the cloud cover extending down to 3,000 feet at times. At 1430 and 10 miles downwind from the source, a smoke plume cross section made from the aircraft flying 600 feet above the terrain showed a definite increase in particle concentration toward the side of the fire where maximum fuel was being consumed (Fig. 6). The plume width had increased by a factor of about six at this distance from the source (Fig. 7).

Absolute particulate density measurements taken near the ground for specific points in time are not available for this fire. However, high-volume air samplers were used to collect total particulates over 24-hour periods. The average particulate concentration for the samplers by sampling period was computed and is listed in Table 1. Concentrations of particulate for the high-volume air sampler No. 1

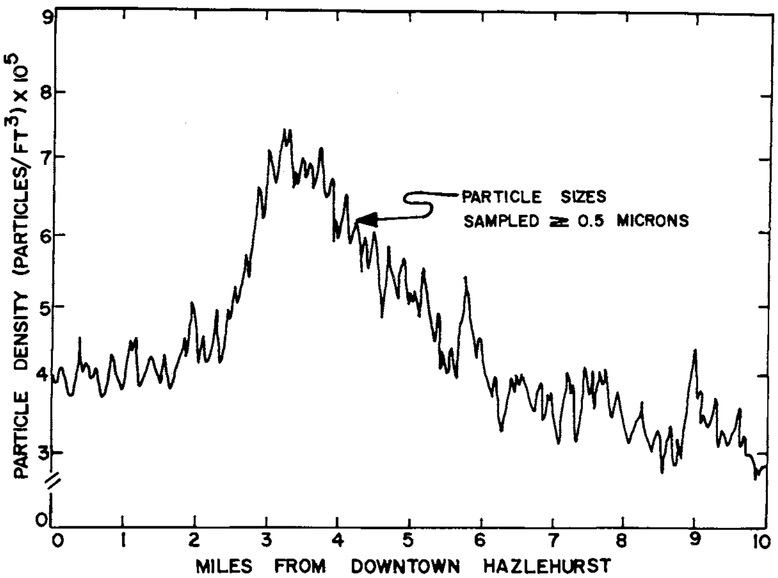

FIG. 6. Smoke plume cross section made while flying in a northerly direction from Hazelhurst, Georgia, and approximately 10 miles downwind from the Lumber City prescribed burn.

TABLE 1. PARTICULATE WEIGHT IN MICROGRAMS PER CUBIC METER OF AIR SAMPLED FOR THREE DIFFERENT DAYS WITH HIGH-VOLUME AIR SAMPLERS AT STRATEGIC LOCATIONS DOWNWIND FROM THE LUMBER CITY PRESCRIBED BURN

Date	Control	No. 1	No. 2	No. 3	No. 4
Friday, 3/13	33.45	56.63	31.66	40.71	30.19
Saturday, 3/14	35.59	44.02	34.02	35.05	28.92
Sunday, 3/15	28.37	31.12	27.40	30.76	24.39

were 82 percent higher and sampler No. 3 were 33 percent higher on March 13 than the samples collected Sunday, March 15. Both samplers were in the smoke plume. The control sampler was upwind. (See Figure 7 for sampler locations relative to the location of the smoke plume). Three other samplers ranged from 15 to 23 percent higher for the same dates. Particulate concentrations recorded were all lower than the 80 $\mu g/m^3$ HEW standard. No vertical comparison is possible between the smoke particle weights per cubic meter

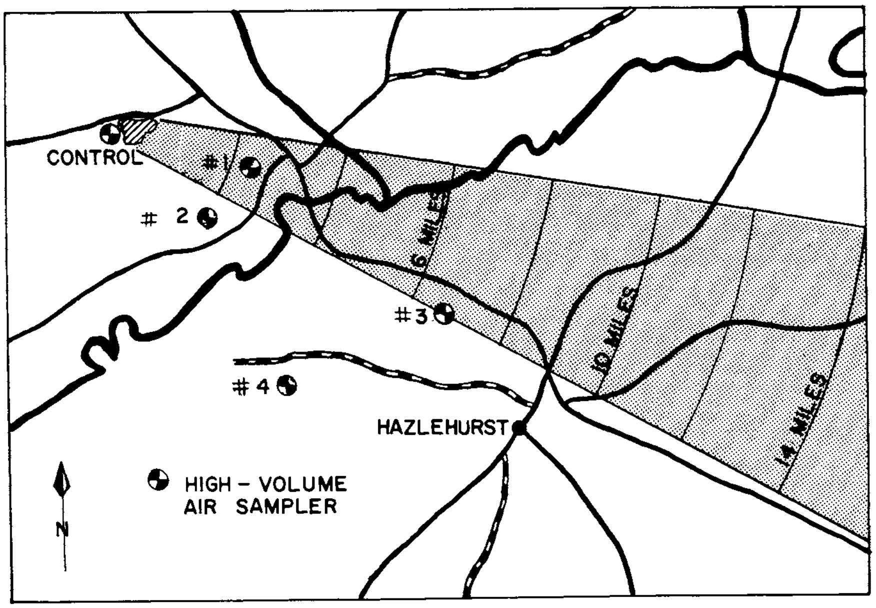

FIG. 7. Smoke plume dispersion fan from the Lumber City prescribed burn. Locations of high-volume air samplers relative to the plume path are illustrated.

recorded at ground level and the number of particles counted at an altitude of 600 feet. In essence, the relationship between smoke particle mass and smoke particle size is not clearly defined.

To supplement future field burns, individual fuel components from the fuel complex will be sampled and returned to Macon for laboratory analyses. Gaseous and particulate emissions for differing fuel and weather conditions will be measured. Then, hopefully, it will be possible to write a prescription, or prescriptions, for burning this fuel under conditions favorable for smoke dispersion while accomplishing the land manager's objective.

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